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RNA PROCESSING PROTEIN COMPLEXES AND USES THEREOF

Abstract:

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The invention provides human protein complexes with endonuclease activity. In particular, the invention provides human protein complexes with tRNA splicing endonuclease activity and/or 3' end pre-mRNA endonuclease activity. The invention also provides a splice variant of human Sen2, namely human Sen2deltaEx8, and human protein complexes comprising human Sen2deltaEx8. The human Sen2deltaEx8 complexes have pre-tRNA cleavage activity and/or 3' end pre-mRNA endonuclease activity. The invention also provides human protein complexes with pre-ribosomal RNA cleavage activity. The invention also provides antibodies that immunospecifically bind to a complex described herein or a component thereof, and methods of diagnosing, preventing, treating, managing or ameliorating a disorder utilizing such antibodies. The present invention also provides methods utilizing the complexes described herein, inter alia, in screening, diagnosis, and therapy. The invention further provides methods of preparing and purifying the complexes. The present invention further provides methods of identifying a compound that modulates the expression of a component of a complex described herein, the formation of a complex described herein or the activity of a complex described herein, and methods of preventing, treating, managing or ameliorating a disorder, such as a proliferative disorder, or a symptom thereof utilizing a compound identified in accordance with the methods.

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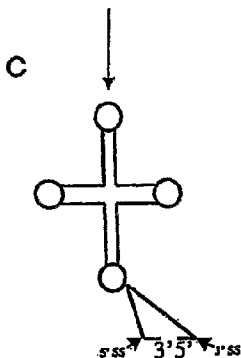
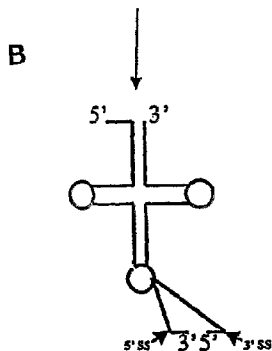
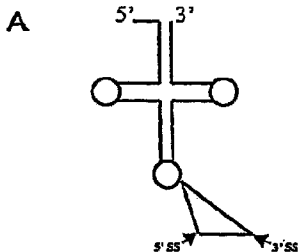
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(54) Title: RNA PROCESSING PROTEIN COMPLEXES AND USES THEREOF

HTS Fluorescent Screening



(57) Abstract: The invention provides human protein complexes with endonuclease activity. In particular, the invention provides human protein complexes with tRNA splicing endonuclease activity and/or 3' end pre-mRNA endonuclease activity. The invention also provides a splice variant of human Sen2, namely human Sen2deltaEx8, and human protein complexes comprising human Sen2deltaEx8. The human Sen2deltaEx8 complexes have pre-tRNA cleavage activity and/or 3' end pre-mRNA endonuclease activity. The invention also provides human protein complexes with pre-ribosomal RNA cleavage activity. The invention also provides antibodies that immunospecifically bind to a complex described herein or a component thereof, and methods of diagnosing, preventing, treating, managing or ameliorating a disorder utilizing such antibodies. The present invention also provides methods utilizing the complexes described herein, *inter alia*, in screening, diagnosis, and therapy. The invention further provides methods of preparing and purifying the complexes. The present invention further provides methods of identifying a compound that modulates the expression of a component of a complex described herein, the formation of a complex described herein or the activity of a complex described herein, and methods of preventing, treating, managing or ameliorating a disorder, such as a proliferative disorder, or a symptom thereof utilizing a compound identified in accordance with the methods.



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## RNA PROCESSING PROTEIN COMPLEXES AND USES THEREOF

### Related Application

This application claims the benefit of U.S. Provisional Application Serial No. 60/484,615, filed July 2, 2003, the entire disclosure of which is incorporated by reference herein in its entirety.

### 1. INTRODUCTION

The invention provides human protein complexes with endonuclease activity. In particular, the invention provides human protein complexes with tRNA splicing endonuclease activity and/or 3' end pre-mRNA endonuclease activity. The invention also provides a splice variant of human Sen2, namely human Sen2deltaEx8, and human protein complexes comprising human Sen2deltaEx8. The human Sen2deltaEx8 complexes have RNA-nucleolytic activity. The invention also provides human protein complexes with pre-ribosomal RNA cleavage activity. The invention also provides antibodies that immunospecifically bind to a complex described herein or a component thereof, and methods of diagnosing, preventing, treating, managing or ameliorating a disorder utilizing such antibodies. The present invention also provides methods utilizing the complexes described herein, *inter alia*, in screening, diagnosis, and therapy. The invention further provides methods of preparing and purifying the complexes. The present invention further provides methods of identifying a compound that modulates the expression of a component of a complex described herein, the formation of a complex described herein or the activity of a complex described herein, and methods of preventing, treating, managing or ameliorating a disorder, such as a proliferative disorder, or a symptom thereof utilizing a compound identified in accordance with the methods.

### 2. BACKGROUND OF THE INVENTION

#### 2.1 tRNA Production

Maturation and maintenance of tRNA within eucaryal cells requires several processing events including 5' and 3' end-trimming, modification of specific bases and in some cases, intron removal. The enzymes for these various steps in processing have been characterized in



the yeast, archaeal, mammalian and bacterial systems (Deutscher, M.P. tRNA Processing Nucleases, in tRNA: Structure, Biosynthesis and Function, D. Soll and U. RajBhandary (eds.), American Society for Microbiology, Washington DC, (1995), pp. 51-65). 5' end trimming requires the activity of Rnase P and 3' end trimming requires the function of various endo- and

5    exo- nucleases. Modification occurs through interaction of tRNA with various modification enzymes. Most tRNAs contain a number of global as well as, species-specific modifications (Bjork, G. Biosynthesis and Function of Modified Nucleosides, in tRNA: Structure, Biosynthesis and Function, D. Soll and U. RajBhandary (eds.), American Society for Microbiology, Washington DC, (1995), pp. 165-205). In archaea and eucarya, several

10   isoaccepting groups of tRNA contain intervening sequences ranging in size from 14-105 nucleotides (Trotta, C.R. and Abelson, J.N. tRNA Splicing: An RNA World Add-On or an Ancient Reaction? In RNA World II, Tom Cech, Ray Gesteland and John Atkins (eds.), Cold Spring Harbor Laboratory Press (1999) and Abelson et al., 1998, Journal of Biological Chemistry 273:12685-12688). Removal of the intron requires the activity of 3 enzymes. In the

15   first step, the tRNA is recognized and cleaved at the 5' and 3' junction by the tRNA splicing endonuclease. The archaeal and eucaryal tRNA endonuclease are evolutionary conserved enzymes and contain a similar active site to achieve cleavage at the 5' and 3' splice sites. However, they have diverged to recognize the tRNA substrate in a different manner. The archaeal enzyme recognizes a conserved intronic structure known as the bulge-helix-bulge. This

20   structure is comprised of two 3-nucleotide bulges separated by a 4-nucleotide helix. Cleavage occurs within each bulge to release the intron. The eucaryal endonuclease recognizes the tRNA substrate in a mature domain dependent fashion, measuring a set distance from the mature domain to the 5' and 3' splice sites (Reyes et al., 1988, Cell 55:719-730). It has recently been demonstrated, however, that the eucaryal enzyme requires a bulge at each splice site and that the

25   enzyme has actually retained the ability to recognize tRNA by an intron-dependent recognition mechanism identical to that of the archaeal endonuclease (Fruscoloni et al., 2001, EMBO Rep 2:217-221). Once cleaved, the tRNA half molecules are ligated by the action of a unique tRNA splicing ligase (Trotta, C.R. and Abelson, J.N. tRNA Splicing: An RNA World Add-On or an Ancient Reaction? In RNA World II, Tom Cech, Ray Gesteland and John Atkins (eds.), Cold

30   Spring Harbor Laboratory Press (1999) and Abelson et al., 1998, Journal of Biological Chemistry 273:12685-12688). In yeast, the product of ligation is a tRNA with a phosphate at the splice junction. Removal of the phosphate is carried out by a tRNA 2'-phosphotransferase to yield a mature tRNA product (Trotta, C.R. and Abelson, J.N. tRNA Splicing: An RNA World

Add-On or an Ancient Reaction? In RNA World II, Tom Cech, Ray Gesteland and John Atkins (eds.), Cold Spring Harbor Laboratory Press (1999) and Abelson et al., 1998, Journal of Biological Chemistry 273:12685-12688).

tRNA is an important component in the translational machinery and is quite stable  
5 compared to various other protein-based components (elongation factors, amino-acyl  
synthetases, *etc.*). tRNA molecules have very long half-lives. Furthermore, like rRNA and  
ribosomes, tRNA is present in excess within the cytoplasm of actively growing cells (Ikemura,  
T. and Okeki, H., 1983, Cold Spring Harbor Symp. Quant. Biol. 47:1087-1097). Thus, specific  
targeting of tRNA molecules allows a selective inhibition of uncontrolled cell proliferation and  
10 not cell growth.

## 2.2 Pre-mRNA Cleavage

Several processing steps are required before eukaryotic mRNA precursors (pre-mRNAs)  
are exported to the cytoplasm. Pre-mRNA processing includes capping of the 5' end, splicing,  
15 and the generation of a new 3' end by endonucleolytic cleavage and polyadenylation.  
Transcription, capping, splicing and 3' end processing of pre-mRNAs are coupled processes *in*  
*vivo* (reviewed in Barabino and Kelly, 1999, *Cell*, 99, 9-11; Minvielle-Sebastia and Keller, 1999,  
*Curr. Opin. Cell Biol.*, 11, 352-357; Zhao et al., 1999, *Microbiol. Mol. Biol. Rev.*, 63, 405-445;  
Hirose and Manley, 2000, *Genes Dev.*, 14, 1415-1429; and Proudfoot, 2000, *Trends Biochem.*  
20 *Sci.*, 25, 290-293).

The 3' end of the pre-mRNAs are generated in a two-step reaction. The pre-mRNA is  
first cleaved endonucleolytically and the upstream cleavage fragment is subsequently  
polyadenylated and the downstream cleavage product is subsequently degraded. Six *trans*-  
acting factors are required for the *in vitro* reconstitution of mammalian 3' end processing,  
25 namely CPSF, CstF, CF I<sub>m</sub>, CFII<sub>m</sub>, PAP, PABP2 (reviewed in Wahle and Ruegsegger, 1999,  
*FEMS Micro Rev.*, 23, 277-295; and Zhao et al., 1999, *Microbiol. Mol. Biol. Rev.*, 63, 405-445).  
Cleavage and polyadenylation specificity factor (CPSF) and cleave stimulation factor (CstF)  
recognize the hexanucleotide AAUAAA upstream and a G/U-rich sequence element  
downstream of the cleavage site, respectively. In addition, the cleavage complex contains  
30 cleavage factors I<sub>m</sub> (CF I<sub>m</sub>) and II<sub>m</sub> (CF II<sub>m</sub>) and poly(A) polymerase (PAP). After the first step,  
CstF, CF I<sub>m</sub> and CF II<sub>m</sub> are released together with the downstream cleavage fragment. CPSF  
remains bound to the upstream cleavage product and tethers PAP to the RNA. PAP is the

enzyme responsible for the addition of the poly(A) tail in a processing reaction that also requires both CPSF and poly(A)-binding protein II (PABP2).

### 5                    **2.3 Cancer and Neoplastic Disease**

Cancer is the second leading cause of death in the United States. The American Cancer Society estimated that in 2001, there would be 1.3 million new cases of cancer and that cancer will cause 550,000 deaths. Overall rates have declined by 1% per year during the 1990s. There are 9 million Americans alive who have ever had cancer. NIH estimates the direct medical costs  
10 of cancer as \$60 billion.

Currently, cancer therapy involves surgery, chemotherapy and/or radiation treatment to eradicate neoplastic cells in a patient (see, for example, Stockdale, 1998, "Principles of Cancer Patient Management", in Scientific American: Medicine, vol. 3, Rubenstein and Federman, eds., Chapter 12, Section IV). All of these approaches pose significant drawbacks for the  
15 patient. Surgery, for example, can be contraindicated due to the health of the patient or can be unacceptable to the patient. Additionally, surgery might not completely remove the neoplastic tissue. Radiation therapy is effective only when the irradiated neoplastic tissue exhibits a higher sensitivity to radiation than normal tissue, and radiation therapy can also often elicit serious side effects. (*Id.*) With respect to chemotherapy, there are a variety of chemotherapeutic agents  
20 available for treatment of neoplastic disease. However, despite the availability of a variety of chemotherapeutic agents, traditional chemotherapy has many drawbacks (see, for example, Stockdale, 1998, "Principles Of Cancer Patient Management" in Scientific American Medicine, vol. 3, Rubenstein and Federman, eds., ch. 12, sect. 10). Almost all chemotherapeutic agents are toxic, and chemotherapy can cause significant, and often dangerous, side effects, including  
25 severe nausea, bone marrow depression, immunosuppression, etc. Additionally, many tumor cells are resistant or develop resistance to chemotherapeutic agents through multi-drug resistance.

Therefore, there is a significant need in the art for novel compounds and compositions, and methods that are useful for treating cancer or neoplastic disease with reduced or without the  
30 aforementioned side effects. Further, there is a need for cancer treatments that provide cancer-cell-specific therapies with increased specificity and decreased toxicity.

Citation of any reference herein is not to be construed as an admission of its availability as prior art.

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### 3. SUMMARY OF THE INVENTION

The invention provides complexes involved in the processing of RNA. In particular the invention provides complexes with RNA-nucleolytic activity that are involved in pre-tRNA splicing, 3' end pre-mRNA endonuclease activity, pre-tRNA cleavage activity, and/or the pre-  
10 ribosomal RNA cleavage activity. More specifically, the invention provides a purified complex with RNA-nucleolytic activity comprising two or more or any combination of the following (i) human Sen2 or a functionally active derivative or a functionally active fragment thereof; (ii) human Sen 15 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen34 or a functionally active derivative or a functionally active fragment thereof; and  
15 (iv) human Sen54 or a functionally active derivative or a functionally active fragment thereof.

The invention provides a purified protein complex with endonuclease activity comprising: (i) human Sen2 or a functionally active derivative or a functionally active fragment thereof; (ii) human Sen 15 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen34 or a functionally active derivative or a functionally active fragment  
20 thereof; and (iv) human Sen54 or a functionally active derivative or a functionally active fragment thereof. In a specific embodiment, the protein complex has tRNA splicing endonuclease activity. In another embodiment, the protein complex has 3' end pre-mRNA endonuclease activity. In yet another embodiment, the protein complex has tRNA splicing endonuclease activity and 3' end pre-mRNA endonuclease activity.

25 In a specific embodiment, the invention provides a purified complex with endonuclease activity comprising: (i) human Sen2 (ACCESSION NO.: NP\_079541), or a protein encoded by a nucleic acid that hybridizes to the human Sen2 encoding nucleic acid (ACCESSION NO.: NM\_025265) or its complement under high stringency conditions; (ii) human Sen15 (ACCESSION NO.: NP\_443197), or a protein encoded by a nucleic acid that hybridizes to the  
30 human Sen15 encoding nucleic acid (ACCESSION NO.: NM\_052965) or its complement under high stringency conditions; (iii) human Sen34 (ACCESSION NO.: NP\_076980), or a protein encoded by a nucleic acid that hybridizes to the human Sen34 encoding nucleic acid

(ACCESSION NO.:NM\_024075) or its complement under high stringency conditions; and (iv) Sen54 (ACCESSION NO.:XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the human Sen54 encoding nucleic acid (ACCESSION NO.:XM\_208944) or its complement under high stringency conditions. In accordance with this embodiment, the complex has tRNA  
5 splicing endonuclease activity and/or 3'end pre-mRNA endonuclease activity.

The invention also provides a purified protein complex with endonuclease activity comprising: (i) human Sen2 or a functionally active derivative or a functionally active fragment thereof; (ii) human Sen 15 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen34 or a functionally active derivative or a functionally active fragment  
10 thereof; (iv) human Sen54 or a functionally active derivative or a functionally active fragment thereof; and (v) human Clp1 or a functionally active derivative or a functionally active fragment thereof. In a specific embodiment, the protein complex has tRNA splicing endonuclease activity. In another embodiment, the protein complex has 3' end pre-mRNA endonuclease activity. In yet another embodiment, the protein complex has tRNA splicing endonuclease  
15 activity and 3' end pre-mRNA endonuclease activity.

In a specific embodiment, the invention provides a purified complex with endonuclease activity comprising: (i) human Sen2 (ACCESSION NO.: NP\_079541), or a protein encoded by a nucleic acid that hybridizes to the human Sen2 encoding nucleic acid (ACCESSION NO.: NM\_025265) or its complement under high stringency conditions; (ii) human Sen15  
20 (ACCESSION NO.:NP\_443197), or a protein encoded by a nucleic acid that hybridizes to the human Sen15 encoding nucleic acid (ACCESSION NO.:NM\_052965) or its complement under high stringency conditions; (iii) human Sen34 (ACCESSION NO.:NP\_076980), or a protein encoded by a nucleic acid that hybridizes to the human Sen34 encoding nucleic acid (ACCESSION NO.:NM\_024075) or its complement under high stringency conditions; (iv)  
25 Sen54 (ACCESSION NO.:XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the human Sen54 encoding nucleic acid (ACCESSION NO.:XM\_208944) or its complement under high stringency conditions; and (v) human Clp1 (ACCESSION NO.:NP\_006822) or a protein encoded by a nucleic acid that hybridizes to the human Clp1 encoding nucleic acid (ACCESSION NO.: NM\_006831) or its complement under high stringency conditions. In  
30 accordance with this embodiment, the complex has tRNA splicing endonuclease activity and/or 3'end pre-mRNA endonuclease activity.

The invention provides a purified protein complex with endonuclease activity comprising: (i) human Sen2 or a functionally active derivative or a functionally active fragment

thereof; (ii) human Sen 15 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen34 or a functionally active derivative or a functionally active fragment thereof; (iv) human Sen54 or a functionally active derivative or a functionally active fragment thereof; (v) human Clp1 (ACCESSION NO.:NP\_006822) or a functionally active derivative or a functionally active fragment thereof; (vi) human Cleavage-Polyadenylation Specificity Factor ("CPSF") or a functionally active derivative or a functionally active fragment thereof; (vii) human Cleavage Factor I<sub>m</sub> ("CF I<sub>m</sub>") or a functionally active derivative or a functionally active fragment thereof; (viii) human Cleavage Factor II<sub>m</sub> ("CF II<sub>m</sub>") or a functionally active derivative or a functionally active fragment thereof; and (ix) human Cleavage Stimulation Factor ("CSF") or a functionally active derivative or a functionally active fragment thereof. In a specific embodiment, the protein complex has tRNA splicing endonuclease activity. In another embodiment, the protein complex has 3' end pre-mRNA endonuclease activity. In yet another embodiment, the protein complex has tRNA splicing endonuclease activity and 3' end pre-mRNA endonuclease activity.

In one embodiment, the invention provides a purified complex with endonuclease activity comprising: (i) human Sen2 (ACCESSION NO.: NP\_079541), or a protein encoded by a nucleic acid that hybridizes to the human Sen2 encoding nucleic acid (ACCESSION NO.: NM\_025265) or its complement under high stringency conditions; (ii) human Sen15 (ACCESSION NO.:NP\_443197), or a protein encoded by a nucleic acid that hybridizes to the human Sen15 encoding nucleic acid (ACCESSION NO.:NM\_052965) or its complement under high stringency conditions; (iii) human Sen34 (ACCESSION NO.:NP\_076980), or a protein encoded by a nucleic acid that hybridizes to the human Sen34 encoding nucleic acid (ACCESSION NO.:NM\_024075) or its complement under high stringency conditions; (iv) Sen54 (ACCESSION NO.:XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the human Sen54 encoding nucleic acid (ACCESSION NO.:XM\_208944) or its complement under high stringency conditions; (v) human Clp1 (ACCESSION NO.:NP\_006822) or a protein encoded by a nucleic acid that hybridizes to the human Clp1 encoding nucleic acid (ACCESSION NO.: NM\_006831) or its complement under high stringency conditions; (vi) human Cleavage-Polyadenylation Specificity Factor ("CPSF") or proteins encoded by a nucleic acids that hybridize to human CPSF encoding nucleic acids or their complement under high stringency conditions; (vii) human Cleavage Factor I<sub>m</sub> ("CF I<sub>m</sub>") or proteins encoded by nucleic acids that hybridize to human CFI<sub>m</sub> encoding nucleic acids or their complement under high stringency conditions; (viii) human Cleavage Factor II<sub>m</sub> ("CF II<sub>m</sub>") or proteins encoded by

nucleic acids that hybridize to human CFII<sub>m</sub> encoding nucleic acids or their complement under high stringency conditions; and (ix) human Cleavage Stimulation Factor ("CSF") or proteins encoded by nucleic acids that hybridize to human CstF encoding nucleic acids or their complement under high stringency conditions. In accordance with this embodiment, the complex has tRNA splicing endonuclease activity and/or 3' end pre-mRNA endonuclease activity.

The invention provides a purified protein complex with endonuclease activity comprising: (i) human CPSF160 or a functionally active derivative or a functionally active fragment thereof; (ii) human CPSF30 or a functionally active derivative or a functionally active fragment thereof; (iii) human CstF64 or a functionally active derivative or a functionally active fragment thereof; (iv) human symplekin or a functionally active derivative or a functionally active fragment thereof; (v) human Sen2 or a functionally active derivative or a functionally active fragment thereof; (vi) human Sen15 or a functionally active derivative or a functionally active fragment thereof; (vii) human Sen34 or a functionally active derivative or a functionally active fragment thereof; and (viii) human Sen54 or a functionally active derivative or a functionally active fragment thereof. In certain, more specific embodiments, the complex does not comprise PAP (poly(A) polymerase) and Sm proteins (small nuclear ribonucleoprotein). In a specific embodiment, the protein complex has tRNA splicing endonuclease activity. In another embodiment, the protein complex has 3' end pre-mRNA endonuclease activity. In yet another embodiment, the protein complex has tRNA splicing endonuclease activity and 3' end pre-mRNA endonuclease activity. In accordance with this embodiment, the complex has tRNA splicing endonuclease activity and/or 3' end pre-mRNA endonuclease activity.

The invention provides a purified protein complex with endonuclease activity comprising: (i) human CPSF160 or a protein encoded by a nucleic acid that hybridizes to human CPSF160 encoding nucleic acid or its complement under high stringency conditions; (ii) human CPSF30 or a protein encoded by a nucleic acid that hybridizes to human CPSF30 encoding nucleic acid or its complement under high stringency conditions; (iii) human CstF64 or a protein encoded by a nucleic acid that hybridizes to human CstF64 encoding nucleic acid or its complement under high stringency conditions; (iv) human symplekin or a protein encoded by a nucleic acid that hybridizes to human symplekin encoding nucleic acid or its complement under high stringency conditions; (v) human Sen2 or a protein encoded by a nucleic acid that hybridizes to human Sen2 encoding nucleic acid or its complement under high stringency conditions; (vi) human Sen15 or a protein encoded by a nucleic acid that hybridizes to human

Sen15 encoding nucleic acid or its complement under high stringency conditions; (vii) human Sen34 or a protein encoded by a nucleic acid that hybridizes to human Sen34 encoding nucleic acid or its complement under high stringency conditions; and (viii) human Sen54 or a protein encoded by a nucleic acid that hybridizes to human Sen54 encoding nucleic acid or its complement under high stringency conditions. In certain, more specific embodiments, the complex does not comprise PAP (poly(A) polymerase) and Sm proteins (small nuclear ribonucleoprotein). In a specific embodiment, the protein complex has tRNA splicing endonuclease activity. In another embodiment, the protein complex has 3' end pre-mRNA endonuclease activity. In yet another embodiment, the protein complex has tRNA splicing endonuclease activity and 3' end pre-mRNA endonuclease activity. In accordance with this embodiment, the complex has tRNA splicing endonuclease activity and/or 3' end pre-mRNA endonuclease activity.

The invention provides a splice variant of human Sen2, namely human Sen2deltaEx8. In particular, the invention provides nucleic acid sequences encoding human Sen2deltaEx8 or a functionally active fragment or a functionally active derivative thereof, and amino acid sequences coding human Sen2deltaEx8 or a functionally active fragment or a functionally active derivative thereof. In a specific embodiment, the invention provides a nucleic acid sequence that hybridizes under stringent conditions to a nucleic acid sequence encoding Sen2ΔEx8 over the entire length of the nucleic acid sequence encoding Sen2ΔEx8. Preferably, such a nucleic acid sequence encodes a protein having Sen2ΔEx8 activity (such as the ability to form a complex with Clp1 and Sen54). In another embodiment, the invention provides nucleic acid sequences that encode a protein having an amino acid sequence that is at least 90%, preferably at least 95%, at least 98%, at least 99%, at least 99.5%, at least 99.8% or at least 99.9% identical to the amino acid sequence of SEQ ID NO:12, wherein the protein is different from Sen2 (Accession No.: NP\_079541). Preferably, such a protein has Sen2ΔEx8 activity. In another embodiment, the invention provides a nucleic acid sequence comprising the nucleic acid sequence of SEQ ID NO:11. The invention further provides vectors comprising a nucleic acid sequence encoding human Sen2ΔEx8 and host cells comprising the vector. The invention further provides host cells comprising a nucleic acid encoding human Sen2ΔEx8.

The invention provides a purified protein, wherein the protein consists essentially of the amino acid sequence of SEQ ID NO:12 or an amino acid sequence that is at least 90%, preferably at least 95%, at least 98%, at least 99%, at least 99.5%, at least 99.8% or at least 99.9% identical to the amino acid sequence of SEQ ID NO:12. The invention further provides



antibodies or fragments thereof that immunospecifically bind to human Sen2ΔEx8 but do not bind to Sen2. In particular, the invention provides an antibody or fragment thereof that immunospecifically binds to the unique region of Sen2ΔEx8 that is created by the deletion of Exon 8 from the Sen2 protein.

5           The invention also provides purified protein complexes comprising human Sen2deltaEx8. In particular, the invention provides purified protein complexes comprising human Sen2deltaEx8 or a functionally active derivative or a functionally active fragment thereof and one or more, or any combination of the following (i) human Sen54 or a functionally active derivative or a functionally active fragment thereof; (ii) human Sen15 or a functionally active  
10       derivative or a functionally active fragment thereof; and (iii) human Sen34 or a functionally active derivative or a functionally active fragment thereof.

          The Sen2deltaEx8 complexes have RNA-nucleolytic activity. In a specific embodiment, Sen2deltaEx8 complexes have pre-tRNA cleavage activity and/or 3' end pre-mRNA endonuclease activity. The invention provides a purified human Sen2deltaEx8 complex  
15       comprising: (i) human Sen2deltaEx8 or a functionally active derivative thereof; and (ii) human Sen54 or a functionally active derivative or a functionally active fragment thereof. The invention also provides a human Sen2deltaEx8 complex comprising: (i) human Sen2deltaEx8 or a functionally active derivative thereof; (ii) human Sen54 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen15 or a functionally active derivative or a  
20       functionally active fragment thereof; and (iv) human Sen34 or a functionally active derivative or a functionally active fragment thereof. In a specific embodiment, the complex has RNA-nucleolytic activity. In a specific embodiment, the complex has tRNA endonuclease activity. In a specific embodiment, the complex has 3' end mRNA processing activity. These human Sen2deltaEx8 complexes cleave tRNA at multiple sites and are useful in mapping RNA  
25       structure and 3' end pre-mRNA endonuclease processing. In certain embodiments, the fidelity and accuracy of the tRNA cleavage activity of a Sen2deltaEx8 comprising complex is reduced compared to the the tRNA cleavage activity of full length Sen2 comprising complexes.

          In a specific embodiment, the invention provides a purified human Sen2deltaEx8 complex comprising: (i) human Sen2deltaEx8 (SEQ ID NO.: 2), or a functionally active  
30       fragment thereof or a protein encoded by a nucleic acid that hybridizes to the human Sen2deltaEx8 encoding nucleic acid (SEQ ID NO.: 1) or its complement under high stringency conditions; and (ii) human Sen15 (ACCESSION NO.:NP\_443197), or a protein encoded by a nucleic acid that hybridizes to the human Sen15 encoding nucleic acid (ACCESSION

NO.:NM\_052965) or its complement under high stringency conditions. In another embodiment, the invention provides a purified human Sen2deltaEx8 complex comprising: (i) human Sen2deltaEx8 (SEQ ID NO.: 2), or a protein encoded by a nucleic acid that hybridizes to the human Sen2deltaEx8 encoding nucleic acid (SEQ ID NO.: 1) or its complement under high stringency conditions; (ii) human Sen15 (ACCESSION NO.:NP\_443197), or a protein encoded by a nucleic acid that hybridizes to the human Sen15 encoding nucleic acid (ACCESSION NO.:NM\_052965) or its complement under high stringency conditions; (iii) human Sen34 (ACCESSION NO.:NP\_076980), or a protein encoded by a nucleic acid that hybridizes to the human Sen34 encoding nucleic acid (ACCESSION NO.:NM\_024075) or its complement under high stringency conditions; and (iv) Sen54 (ACCESSION NO.:XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the human Sen54 encoding nucleic acid (ACCESSION NO.:XM\_208944) or its complement under high stringency conditions.

In certain embodiments, the invention provides a purified human Sen2deltaEx8 complex comprising: (i) human Sen2deltaEx8; and (ii) human Sen34. In certain embodiments, the invention provides a purified human Sen2deltaEx8 complex comprising: (i) human Sen2deltaEx8; (ii) human Sen15; and (iii) human Sen34. In certain embodiments, the invention provides a purified human Sen2deltaEx8 complex comprising: (i) Sen2deltaEx8; and (ii) Sen54.

In accordance with these embodiments, the human Sen2deltaEx8 complex has RNA-nucleolytic activity. In a particular embodiment, the human Sen2deltaEx8 complex cleaves tRNA at multiple sites. These human Sen2deltaEx8 complexes are useful in mapping RNA structure and 3' endonuclease processing. In certain embodiments, the fidelity and accuracy of the tRNA cleavage activity of a Sen2deltaEx8 comprising complex is reduced compared to the tRNA cleavage activity of full length Sen2 comprising complexes.

In certain embodiments, the invention provides a purified human Sen2deltaEx8 complex comprising: (i) human Sen2deltaEx8 or a protein encoded by a nucleic acid that hybridizes to the human Sen2deltaEx8 encoding nucleic acid; and (ii) human Sen34 or a protein encoded by a nucleic acid that hybridizes to the human Sen34 encoding nucleic acid. In certain embodiments, the invention provides a purified human Sen2deltaEx8 complex comprising: (i) human Sen2deltaEx8 or a protein encoded by a nucleic acid that hybridizes to the human Sen2deltaEx8 encoding nucleic acid; (ii) human Sen15 or a protein encoded by a nucleic acid that hybridizes to the human Sen15 encoding nucleic acid; and (iii) human Sen34 or a protein encoded by a nucleic acid that hybridizes to the human Sen34 encoding nucleic acid. In certain embodiments, the invention provides a purified human Sen2deltaEx8 complex comprising: (i) Sen2deltaEx8 or

a protein encoded by a nucleic acid that hybridizes to the human Sen2deltaEx8 encoding nucleic acid; and (ii) Sen54 or a protein encoded by a nucleic acid that hybridizes to the human Sen54 encoding nucleic acid.

The invention provides a purified human Sen2deltaEx8 complex with 3' end pre-mRNA  
5 endonuclease activity comprising: (i) human Sen2deltaEx8 or a functionally active derivative thereof; (ii) human Sen54 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen15 or a functionally active derivative or a functionally active fragment thereof; (iv) human Sen34 or a functionally active derivative or a functionally active fragment thereof; and (v) human Clp1 (ACCESSION NO.:NP\_006822) or a functionally active derivative  
10 or a functionally active fragment thereof. In certain embodiments, the complex may further comprise: (i) human CPSF160 or a functionally active derivative or a functionally active fragment thereof; (ii) human CPSF30 or a functionally active derivative or a functionally active fragment thereof; (iii) human CstF64 or a functionally active derivative or a functionally active fragment thereof; and/or (iv) human symplekin or a functionally active derivative or a  
15 functionally active fragment. The invention also provides a purified human Sen2deltaEx8 complex with 3' end pre-mRNA endonuclease activity comprising: (i) human Sen2deltaEx8 or a functionally active derivative thereof; (ii) human Sen54 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen15 or a functionally active derivative or a functionally active fragment thereof; (iv) human Sen34 or a functionally active derivative or a  
20 functionally active fragment thereof; (v) human Clp1 (ACCESSION NO.:NP\_006822) or a functionally active derivative or a functionally active fragment thereof; (vi) human CSPF or a functionally active derivative or a functionally active fragment thereof; (vii) human CFI<sub>m</sub> or a functionally active derivative or a functionally active fragment thereof; (viii) human CFII<sub>m</sub> or a functionally active derivative or a functionally active fragment thereof; and (ix) human CstF or a  
25 functionally active derivative or a functionally active fragment thereof.

In a specific embodiment, the invention provides a purified human Sen2deltaEx8 complex with 3' end pre-mRNA endonuclease activity comprising: (i) human Sen2deltaEx8 (SEQ ID NO.: 2), or a protein encoded by a nucleic acid that hybridizes to the human Sen2deltaEx8 encoding nucleic acid (SEQ ID NO.:11) or its complement under high stringency  
30 conditions; (ii) human Sen54 (ACCESSION NO.:XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the human Sen54 encoding nucleic acid (ACCESSION NO.:XM\_208944) or its complement under high stringency conditions; (iii) human Sen15 (ACCESSION NO.:NP\_443197), or a protein encoded by a nucleic acid that hybridizes to the

human Sen15 encoding nucleic acid (ACCESSION NO.:NM\_052965) or its complement under high stringency conditions; (iv) human Sen34 (ACCESSION NO.:NP\_076980), or a protein encoded by a nucleic acid that hybridizes to the human Sen34 encoding nucleic acid (ACCESSION NO.:NM\_024075) or its complement under high stringency conditions; and (v) 5 human Clp1 (ACCESSION NO.:NP\_006822) or a protein encoded by a nucleic acid that hybridizes to the human Clp1 encoding nucleic acid (ACCESSION NO.: NM\_006831) (ACCESSION NO.: NM\_006831) or its complement under high stringency conditions.

In certain embodiments, the complex may further comprise: (i) human CPSF160 or a protein encoded by a nucleic acid that hybridizes to the human CPSF160 encoding nucleic acid; 10 (ii) human CPSF30 or a protein encoded by a nucleic acid that hybridizes to the human CPSF30 encoding nucleic acid; (iii) human CstF64 or a protein encoded by a nucleic acid that hybridizes to the human CstF64 encoding nucleic acid; and/or (iv) human symplekin or a protein encoded by a nucleic acid that hybridizes to the human symplekin encoding nucleic acid.

In another embodiment, the invention provides a purified human Sen2deltaEx8 complex 15 with 3' end pre-mRNA endonuclease activity comprising: (i) human Sen2deltaEx8 (SEQ ID NO.: 2), or a protein encoded by a nucleic acid that hybridizes to the human Sen2deltaEx8 encoding nucleic acid (SEQ ID NO.: 1) or its complement under high stringency conditions; (ii) human Sen54 (ACCESSION NO.:XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the human Sen54 encoding nucleic acid (ACCESSION NO.:XM\_208944) or its 20 complement under high stringency conditions; (iii) human Sen15 (ACCESSION NO.:NP\_443197), or a protein encoded by a nucleic acid that hybridizes to the human Sen15 encoding nucleic acid (ACCESSION NO.:NM\_052965) or its complement under high stringency conditions; (iv) human Sen34 (ACCESSION NO.:NP\_076980), or a protein encoded by a nucleic acid that hybridizes to the human Sen34 encoding nucleic acid (ACCESSION 25 NO.:NM\_024075) or its complement under high stringency conditions; (v) human Clp1 (ACCESSION NO.:NP\_006822) or a protein encoded by a nucleic acid that hybridizes to the human Clp1 encoding nucleic acid (ACCESSION NO.: NM\_006831) or its complement under high stringency conditions; (vi) a human CPSF, or a protein encoded by a nucleic acid that hybridizes to the human CPSF encoding nucleic acid or its complement under high stringency 30 conditions; (vii) a human CFI<sub>m</sub>, or a protein encoded by a nucleic acid that hybridizes to the human CFI<sub>m</sub> encoding nucleic acid or its complement under high stringency conditions; (viii) a human CFII<sub>m</sub>, or a protein encoded by a nucleic acid that hybridizes to the human CFII<sub>m</sub> encoding nucleic acid or its complement under high stringency conditions; and (ix) human CSF,

or a protein encoded by a nucleic acid that hybridizes to the human CstF encoding nucleic acid or its complement under high stringency conditions.

The invention provides a purified human Sen2deltaEx8 complex with 3' end pre-mRNA endonuclease activity comprising: (i) human Sen2deltaEx8 or a functionally active derivative thereof; (ii) human Sen54 or a functionally active derivative or a functionally active fragment thereof; and (iii) human Clp1 (ACCESSION NO.:NP\_006822) or a functionally active derivative or a functionally active fragment thereof, and optionally one or more, or any combination of the following: (i) human CPSF or a functionally active derivative or a functionally active fragment thereof; (ii) human CFI<sub>m</sub> or a functionally active derivative or a functionally active fragment thereof; (iii) human CFII<sub>m</sub> or a functionally active derivative or a functionally active fragment thereof; and (iv) human CstF or a functionally active derivative or a functionally active fragment thereof. In a specific embodiment, the invention provides a purified Sen2deltaEx8 complex with 3' end pre-mRNA endonuclease activity comprising: (i) human Sen2deltaEx8 (SEQ ID NO.: 2), or a protein encoded by a nucleic acid that hybridizes to the human Sen2deltaEx8 encoding nucleic acid (SEQ ID NO.: 1) or its complement under high stringency conditions; (ii) human Sen54 (ACCESSION NO.:XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the human Sen54 encoding nucleic acid (ACCESSION NO.:XM\_208944) or its complement under high stringency conditions; and (iii) human Clp1 (ACCESSION NO.:NP\_006822) or a protein encoded by a nucleic acid that hybridizes to the human Clp1 encoding nucleic acid (ACCESSION NO.: NM\_006831) or its complement under high stringency conditions. In certain embodiments, the complex may further comprise: (i) human CPSF160 or a protein encoded by a nucleic acid that hybridizes to the human CPSF160 encoding nucleic acid; (ii) human CPSF30 or a protein encoded by a nucleic acid that hybridizes to the human CPSF30 encoding nucleic acid; (iii) human CstF64 or a protein encoded by a nucleic acid that hybridizes to the human CstF64 encoding nucleic acid; and/or (iv) human symplekin or a protein encoded by a nucleic acid that hybridizes to the human symplekin encoding nucleic acid. In another embodiment, the invention provides a purified Sen2deltaEx8 complex with 3' end pre-mRNA endonuclease activity comprising: (i) human Sen2deltaEx8 (SEQ ID NO.: 2), or a protein encoded by a nucleic acid that hybridizes to the human Sen2deltaEx8 encoding nucleic acid (SEQ ID NO.: 1) or its complement under high stringency conditions; (ii) human Sen54 (ACCESSION NO.:XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the human Sen54 encoding nucleic acid (ACCESSION NO.:XM\_208944) or its complement under high stringency conditions; (iii) human Clp1

(ACCESSION NO.:NP\_006822) or a protein encoded by a nucleic acid that hybridizes to the human Clp1 encoding nucleic acid (ACCESSION NO.: NM\_006831) or its complement under high stringency conditions; (iv) human CPSF or a protein encoded by a nucleic acid that hybridizes to the human CPSF or its complement under high stringency conditions; (v) human CFI<sub>m</sub> or a protein encoded by a nucleic acid that hybridizes to the human CFI<sub>m</sub> encoding nucleic acid or its complement under high stringency conditions; (vi) human CF II<sub>m</sub> or a protein encoded by a nucleic acid that hybridizes to the human CFII<sub>m</sub> encoding nucleic acid or its complement under high stringency conditions; and (vii) human CstF or a protein encoded by a nucleic acid that hybridizes to the human CstF encoding nucleic acid or its complement under high stringency conditions.

The invention also provides protein complexes with pre-ribosomal RNA cleavage activity. In particular, the invention provides a protein complex with pre-ribosomal RNA cleavage activity comprising: (i) human Sen15 or a functionally active derivative or a functionally active fragment thereof; and (ii) human Sen34 or a functionally active derivative or a functionally active fragment thereof. More specifically, the invention provides a protein complex with pre-ribosomal RNA cleavage activity comprising: (i) human Sen15 (ACCESSION NO.:NP\_443197), or a protein encoded by a nucleic acid that hybridizes to the human Sen15 encoding nucleic acid (ACCESSION NO.:NM\_052965) or its complement under high stringency conditions; and (ii) human Sen34 (ACCESSION NO.:NP\_076980), or a protein encoded by a nucleic acid that hybridizes to the human Sen34 encoding nucleic acid (ACCESSION NO.:NM\_024075) or its complement under high stringency conditions. This protein complex may be used in the biogenesis of different ribosomal RNAs. For example, the production of 28S, 18S, 5.5S and 5S ribosomal RNA may be altered by modulating this protein complex.

In certain embodiments, at least two protein components, at least three protein components, at least four protein components or at least five protein components of a complex of the invention are covalently linked to each other, *e.g.*, as fusion proteins. In certain other embodiments, a complex of the invention comprises at least two protein components, at least three protein components, at least four protein components or at least five protein components that are non-covalently linked to each other. In yet other embodiments, a complex of the invention comprises a combination of covalently linked and non-covalently linked protein components. In certain other embodiments, a protein component of a complex of the invention is fused to a heterologous amino acid sequence, *i.e.*, an amino acid sequence different from the

protein. Further, the complexes of the invention may comprise at least one, preferably at least two functionally active fragments of protein components of the complex. The complexes of the invention may comprise at least three, at least four or at least five functionally active fragments of protein components of the complex. The complexes of the invention may comprise at least one, preferably at least two or at least three, at least four or at least five functionally active derivatives of the protein components of the complex. In one embodiment, such functionally active derivatives are fusion proteins. In accordance with this embodiment, such fusion proteins may comprise a heterologous sequence, *i.e.*, an amino acid sequence different from the amino acid sequence of the protein component.

The invention provides methods for purifying a complex of the invention. In particular, the invention provides a method for purifying a complex of the invention, the method comprising: preparing a cell extract or a nuclear extract from a cell, wherein the cell expresses all of the protein components of the complex and wherein at least one of the protein components is fused to a peptide tag; and purifying the complex by virtue of the peptide tag.

The invention provides antibodies or fragments thereof that immunospecifically bind to a complex of the invention. In a specific embodiment, the invention provides an antibody or a fragment thereof that immunospecifically binds to a complex of the invention with higher affinity than to each individual component of the complex in an immunoassay well-known to one of skill in the art or described herein. In another embodiment, the invention provides an antibody or a fragment thereof that immunospecifically binds to a complex of the invention, but does not bind to each individual component of the complex in an immunoassay well-known to one of skill in the art or described herein. The invention also provides a method for generating an antibody or a fragment thereof that immunospecifically binds to a complex of the invention comprising immunizing a subject with the complex of the invention.

The invention also provides antibodies or fragments thereof that immunospecifically bind to one of the following components of a complex of the invention: (i) human Sen2 or a functionally active derivative or a functionally active fragment thereof; (ii) human Sen2deltaEx8 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen15 or a functionally active derivative or a functionally active fragment thereof; (iv) human Sen34 or a functionally active derivative or a functionally active fragment thereof; and (v) human Sen54 or a functionally active derivative or a functionally active fragment thereof. Preferably, the antibodies or fragments thereof are not known. The invention also provides a method for generating an antibody or a fragment thereof that immunospecifically binds to a component of a

complex of the invention comprising immunizing a subject with the component.

In a specific embodiment, the invention provides an antibody or a fragment thereof that immunospecifically binds to human Sen2deltaEx8 with higher affinity than human Sen2 in an immunoassay well-known to one of skill in the art or described herein. In another embodiment,  
5 the invention provides an antibody or a fragment thereof that immunospecifically binds to human Sen2deltaEx8, but does not bind to human Sen2 in an immunoassay well-known to one of skill in the art or described herein.

The invention provides methods of identifying compounds that modulate the expression (at the RNA and/or protein level) of one or more of the following components of a complex of  
10 the invention: (i) human Sen2 or a functionally active derivative or a functionally active fragment thereof; (ii) human Sen2deltaEx8 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen15 or a functionally active derivative or a functionally active fragment thereof; (iv) human Sen34 or a functionally active derivative or a functionally active fragment thereof; and/or (v) human Sen54 or a functionally active derivative or a  
15 functionally active fragment thereof. Techniques for measuring expression of proteins are well-known to one of skill in the art and include, *e.g.*, immunoassays for protein expression levels, and RT-PCR or Northern blots for RNA expression levels.

The invention provides screening assays to identify compounds that modulate the formation of a complex of the invention. In particular, the invention provides a method of  
20 identifying a compound that modulates the formation of a complex of the invention, the method comprising: contacting a cell with a compound, wherein the cell comprises all of the components of the complex the invention; and measuring the amount of the complex of the invention formed in the cell. The method may further comprise isolating the complex of the invention from the cell. The amount of complex can be measured by any method well-known to  
25 one of skill in the art for measuring complex formation or by any method described herein (such as, *e.g.*, FRET). In a specific embodiment, the invention provides a method of identifying a compound that modulates the formation of a complex, the method comprising: contacting a cell comprising all of the components of the complex with a compound, wherein the cell has been engineered to express one, two, three, four or more of the components of the complex; and  
30 measuring the amount of the complex formed in the cell. In accordance with this embodiment, the cell may be any non-human cell or a human cell deficient in one or more components of the complex.

The invention provides a method of identifying a compound that modulates the



formation of a complex, the method comprising the following steps: (a) incubating the components of a complex of the invention in the presence of a compound under conditions conducive to formation of a complex comprising the proteins; and (b) measuring the amount of the complex, wherein a difference in the amount of the complex measured in step (b) relative to the amount of the complex measured in the absence of the compound or in the presence of an appropriate control (*e.g.*, a negative control such as phosphate buffered saline) or a predetermined reference range indicates that the compound modulates the formation of the complex. Techniques for measuring complex formation are well-known in the art or described herein.

10           The invention provides methods for identifying compounds that modulate the endonucleolytic activity of a complex of the invention. The invention provides cell-based and cell-free assays for identifying compounds that modulate human tRNA splicing endonuclease activity and/or human 3' end pre-mRNA splicing endonuclease activity. In one embodiment, the invention provides a method for identifying compounds that modulate the endonucleolytic activity of a complex of the invention, the method comprising: (a) contacting a compound or a member of a library of compounds with a cell containing or engineered to contain the components of the human complex and a substrate for the complex; and (b) detecting the level of endonucleolytic activity by measuring either the decrease in substrate or the increase in product of the endonuclease reaction. In another embodiment, the invention provides a method for identifying compounds that modulate the endonucleolytic activity of a complex of the invention, the method comprising: (a) incubating a complex of the invention with an endonuclease substrate and with a compound or a member of a library of compounds; and (b) detecting the level of endonuclease activity by measuring either the decrease in substrate or the increase in product of the endonuclease reaction.

25           In a particular embodiment, the invention provides a method for identifying a compound that modulates human tRNA splicing endonuclease activity, the method comprising: contacting a compound or a member of a library of compounds with a complex of the invention with human tRNA splicing endonuclease activity and a nucleic acid (*e.g.*, RNA or DNA) comprising a reporter gene under conditions that allow transcription and translation of the reporter gene (*e.g.*, cell-free or cell-based assays), wherein the reporter gene comprises a tRNA intron; and detecting the expression of said reporter gene (*i.e.*, production of processed reporter gene mRNA resulting from tRNA splicing endonuclease activity, the protein product of the reporter gene, and/or activity of the reporter gene product), wherein a compound that modulates tRNA splicing

endonuclease activity is identified if the expression of said reporter gene in the presence of the compound is altered relative to the expression of said reporter gene in the absence of said compound or the presence of an appropriate control or a predetermined reference range. A decrease in reporter gene expression relative to a previously determined reference range, or to the expression in the absence of the compound or the presence of an appropriate control (*e.g.*, a negative control) in such reporter-gene based assays indicates that a particular compound reduces or inhibits the activity of a human tRNA splicing endonuclease (*e.g.*, the recognition or cleavage of a tRNA intron). In contrast, an increase in reporter gene expression relative to a previously determined reference range, or to the expression in the absence of the compound or the presence of an appropriate control (*e.g.*, a negative control) in such reporter-gene based assays indicates that a particular compound enhances the activity of a human tRNA splicing endonuclease. In a specific embodiment, the TNT<sup>®</sup> Coupled Reticulocyte Lysate Systems is used in accordance with the method (Promega, Madison WI). In other specific embodiments, a cell extract is used to provide the factors required for transcription and translation of the reporter gene. In even other specific embodiments, a compound and the tRNA splicing endonuclease are introduced into a cell (*e.g.*, by transforming a cell with nucleic acids encoding the complex components, preferably under the control of a heterologous promoter). In accordance with this embodiment of the invention, the recombinant components of a complex of the invention can be expressed in the cell either individually or as a fusion complex. In a preferred embodiment, the human complex is introduced or expressed in a non-human cell.

The invention further provides a method for identifying a compound that modulate human tRNA splicing endonuclease activity, said method comprising: (a) expressing a nucleic acid comprising a reporter gene in a cell, wherein the reporter gene comprises a tRNA intron; (b) contacting said cell with a compound or a member of a library of compounds; and (c) detecting the expression of said reporter gene, wherein a compound that modulates tRNA splicing endonuclease activity is identified if the expression of said reporter gene in the presence of a compound is altered relative to a previously determined reference range, or the expression of said reporter gene in the absence of the compound or the presence of an appropriate control (*e.g.*, a negative control). In particular, an increase in expression of the reporter gene compared to a control indicates that the compound increases human tRNA splicing endonuclease activity. In contrast, a decrease in expression of the reporter gene compared to a control indicates that the compound decreases human tRNA splicing endonuclease activity.

In another embodiment, the invention provides a method for identifying a compound that modulates human tRNA splicing endonuclease activity, said method comprising: (a) contacting a member of a library of compounds with a cell containing a nucleic acid comprising a reporter gene, wherein the reporter gene comprises a tRNA intron; and (b) detecting the expression of said reporter gene, wherein a compound that modulates tRNA splicing endonuclease activity is identified if the expression of said reporter gene in the presence of a compound is altered relative to a previously determined reference range, or the expression of said reporter gene in the absence of said compound or the presence of an appropriate control (*e.g.*, a negative control). In particular, an increase in expression of the reporter gene compared to a control indicates that the compound increases human tRNA splicing endonuclease activity. In contrast, a decrease in expression of the reporter gene compared to a control indicates that the compound decreases human tRNA splicing endonuclease activity.

In another embodiment, the invention provides a method for identifying a compound that modulates human tRNA splicing endonuclease activity, the method comprising: contacting a complex of the invention with tRNA splicing endonuclease activity with a substrate of a tRNA splicing endonuclease and a compound or a member of a library of compounds, wherein the substrate is labeled at the 5' end with a fluorophore and at the 3' end with a quencher or, alternatively, the substrate is labeled at the 5' end with a quencher and at the 3' end with a fluorophore; and measuring the activity of the tRNA splicing endonuclease by measuring the change in fluorescence, wherein a compound that modulates tRNA splicing activity is identified if a fluorescent signal is altered in the presence of the compound relative to the signal in the absence of the compound or the presence of an appropriate control. The tRNA splicing endonuclease in the cell-free extract will cleave the substrate and result in the production of a detectable fluorescent signal. A compound that inhibits or reduces the activity of the tRNA splicing endonuclease will inhibit or reduce the cleavage of the substrate and thus, inhibit or reduce the production of a detectable fluorescent signal relative to a negative control (*e.g.*, PBS). A compound that enhances the activity of the tRNA splicing endonuclease will enhance the cleavage of the substrate and thus, increase the production of a detectable signal relative to a negative control (*e.g.*, PBS).

In another embodiment, the invention provides a method for identifying a compound that modulates human tRNA splicing endonuclease activity, the method comprising: contacting a complex of the invention with tRNA splicing endonuclease activity with a substrate of a tRNA splicing endonuclease and a compound or a member of a library of compounds, wherein said

substrate is labeled at the 5' end with a fluorescent donor moiety and labeled at the 3' end with a fluorescent acceptor moiety or, alternatively, the substrate is labeled at the 5' end with a fluorescent acceptor moiety and at the 3' end with a fluorescent donor moiety; and measuring the activity of the tRNA splicing endonuclease, wherein a compound that modulates tRNA

5 splicing activity is identified if the fluorescence emission of the fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety in the presence of the compound is altered relative to the absence of the compound or the presence of an appropriate control (*e.g.*, a negative control such as PBS) or a predetermined reference range. The tRNA splicing endonuclease will cleave the substrate and result in a decrease in the fluorescence emission by

10 the fluorescent donor moiety and fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety. A compound that inhibits or reduces the activity of the human tRNA splicing endonuclease will inhibit or reduce cleavage of the substrate and thus, increase the fluorescence emission of the fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety. A compound that enhances the activity of the human tRNA splicing

15 endonuclease will enhance the cleavage of the substrate and thus, reduce the fluorescence emission of the fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety.

In another embodiment, the invention provides a method for identifying a compound that modulates human 3' end pre-mRNA endonuclease activity, the method comprising: contacting a compound or a member of a library of compounds with a complex of the invention with human

20 3' end pre-mRNA endonuclease activity and a nucleic acid comprising a 3' end cleavage reporter gene, wherein the reporter gene is located 3' of the cleavage site under conditions that allow transcription and translation of the reporter gene (*e.g.*, cell-free or cell based assays); and detecting the expression of said reporter gene (*i.e.*, production of processed mRNA resulting from the 3' end pre-mRNA endonuclease activity cleaving 5' of the reporter gene, amount of the

25 reporter gene product or activity of the reporter gene product), wherein a compound that modulates 3' end pre-mRNA endonuclease activity is identified if the expression of said reporter gene in the presence of a compound is altered relative to the expression of said reporter gene in the absence of said compound or the presence of an appropriate control (*e.g.*, a negative control such as PBS) or to a predetermined reference range. In accordance with this embodiment, all

30 factors required for the expression of the reporter gene are also provided. In a specific embodiment, the TNT<sup>®</sup> Coupled Reticulocyte Lysate Systems is used (Promega, Madison WI). In other specific embodiments, a cell extract is used to provide the factors required for transcription and translation of the reporter gene. In even other specific embodiments, the

complex and the 3' end pre-mRNA endonuclease are introduced into a cell. In particular, an increase in reporter gene expression relative to a previously determined reference range, or to the expression in the absence of the compound or the presence of an appropriate control (*e.g.*, a negative control) in such reporter-gene based assays indicates that a particular compound  
5 reduces or inhibits the activity of a 3' end pre-mRNA endonuclease (*e.g.*, the recognition or cleavage of a substrate). In contrast, a decrease in reporter gene expression relative to a previously determined reference range, or to the expression in the absence of the compound or the presence of an appropriate control (*e.g.*, a negative control) in such reporter-gene based assays indicates that a particular compound enhances the activity of a human 3' end pre-mRNA  
10 endonuclease.

In another embodiment, the invention provides a method of identifying a compound that inhibits or reduces human 3' end pre-mRNA endonuclease activity, the method comprising: contacting a complex of the invention with human 3' end pre-mRNA endonuclease activity with a substrate of a 3' end pre-mRNA endonuclease and a compound or a member of a library of  
15 compounds, wherein the substrate is labeled at the 5' end with a fluorophore and at the 3' end with a quencher or, alternatively, the substrate is labeled at the 5' end with a quencher and at the 3' end with a fluorophore; and measuring the activity of the 3' end pre-mRNA endonuclease; wherein a compound that modulates 3' end pre-mRNA endonuclease activity is identified if a fluorescent signal is altered in the presence of the compound relative to the absence of the  
20 compound or the presence of an appropriate control (*e.g.*, a negative control such as PBS), or to a predetermined reference range. A compound that inhibits or reduces the activity of the human 3' end pre-mRNA endonuclease will inhibit or reduce cleavage of the substrate and thus, decrease the production of a detectable fluorescent signal relative to a control. A compound that enhances the activity of the human 3' end pre-mRNA endonuclease will enhance the cleavage of  
25 the substrate and thus, increase the production of a detectable fluorescent signal relative to a control.

In another embodiment, the invention provides a method of identifying a compound that inhibits or reduces human 3' end pre-mRNA endonuclease activity, the method comprising: contacting a complex of the invention with human 3' end pre-mRNA endonuclease activity with  
30 a substrate of 3' end pre-mRNA endonuclease and a compound or a member of a library of compounds, wherein said substrate is labeled at the 5' end with a fluorescent donor moiety and labeled at the 3' end with a fluorescent acceptor moiety or, alternatively, the substrate is labeled at the 5' end with a fluorescent acceptor moiety and at the 3' end with a fluorescent donor moiety;

and measuring the activity of the 3' mRNA endonuclease, wherein a compound that modulates 3' end pre-mRNA endonuclease activity is identified if the fluorescence emission of the fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety in the presence of the compound is altered in the presence of the compound relative to the absence of the compound or the presence of an appropriate control (*e.g.*, a negative control such as PBS), or to a predetermined reference range. A compound that inhibits or reduces the activity of the human 3' end pre-mRNA endonuclease will inhibit or reduce cleavage of the substrate and thus, increase the fluorescence emission of the fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety relative to a control. A compound that enhances the activity of the human 3' end pre-mRNA endonuclease will enhance the cleavage of the substrate and thus, reduce the fluorescence emission of the fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety.

In certain embodiments, RT-PCR, such as, but not limited to a quantitative RT-PCR assay as described in section 5.2, can be used to measure the effect of a compound on 3' end pre-mRNA processing; the modification of any expressed gene, *e.g.*, GAPDH and EF1A, can be used.

The present invention further provides methods for identifying compounds that modulate the pre-tRNA cleavage activity and/or pre-ribosomal RNA cleavage activity of a complex of the invention. Techniques well-known to one of skill in the art or described herein may be used to measure the ability of a compound to modulate the pre-tRNA cleavage activity and/or pre-ribosomal RNA cleavage activity of a complex of the invention. For example, the ability of a compound to modulate the pre-tRNA cleavage activity of a complex of the invention may be determined by comparing the level of tRNA fragments produced from a tRNA in the presence of the compound relative to the level of tRNA fragments produced from the same tRNA in the absence of the compound or the presence of an appropriate control (*e.g.*, a negative control such as PBS), wherein a change in the levels indicates that the compound modulates the pre-tRNA cleavage activity of the complex. The ability of a compound to modulate the pre-ribosomal RNA cleavage activity of a complex of the invention may be determined by, *e.g.*, comparing the level of specific ribosomal RNAs (*e.g.*, 28S, 18S, 5.8S and/or 5S) produced from a pre-ribosomal RNA in the presence of the compound relative to the level of the ribosomal RNA produced from the same pre-ribosomal RNA in the absence of the compound or the presence of an appropriate control (*e.g.*, a negative control such as PBS), wherein a change in the levels indicates that the compound modulates the pre-ribosomal RNA cleavage activity of the complex.

In certain embodiments, the methods for identifying compounds that modulate the pre-tRNA cleavage activity and/or pre-ribosomal RNA cleavage activity of a complex of the invention are cell-based assays. In other embodiments, the methods for identifying compounds that modulate the pre-tRNA cleavage activity and/or pre-ribosomal RNA cleavage activity of a complex of the invention are cell-free assays.

A compound identified in the assays described herein that modulates the expression of a component of a complex of the invention, the formation of a complex of the invention, the RNA-nucleolytic activity of a complex of the invention (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention) may be tested in *in vitro* assays (*e.g.*, cell-based assays or cell-free assays) and/or *in vivo* assays well-known to one of skill in the art or described herein for the effect of the compound a disorder described herein (*e.g.*, a proliferative disorder or a disorder characterized by, associated with or caused by abnormal RNA-nucleolytic activity) or on cells from a patient with a particular disorder.

In a specific embodiment, a compound identified in the assays described herein that inhibits or reduces the expression of a component of a complex of the invention, the formation of a complex of the invention, the RNA-nucleolytic activity of a complex of the invention (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention) may be tested in *in vitro* assays (*e.g.*, cell-based assays or cell-free assays) and/or *in vivo* assays well-known to one of skill in the art or described herein for the antiproliferative effect of the compound on hyperproliferative cells versus normal cells. In another embodiment, a compound identified in the assays described herein that inhibits or reduces the expression of a component of a complex of the invention, the formation of a complex of the invention, the RNA-nucleolytic activity of a complex of the invention (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention) may be tested in an animal model for cancer to determine the efficacy of the compound in the prevention, treatment or amelioration of cancer or a symptom thereof. In yet another embodiment, a compound identified in assays described herein that enhances the expression of a component of a complex of the invention, the formation of a complex of the invention, the RNA-nucleolytic activity of a complex of the invention (*e.g.*, the

pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention) may be tested for its effect on wound healing.

In a specific embodiment, a compound identified in the assays described herein can be used to assess the function of a complex of the invention or a component of a complex of the invention in different cellular contexts and/or under different biological conditions. For example, cells obtained from different pathological tissues can be contacted with a compound identified in the assays of the invention to test the function of a complex of the invention in such cells.

In even other embodiments, a compound identified in the assays of the invention can be used to modulate expression of a recombinant protein in a cell. For example, a compound that increases the function of human tRNA splicing endonuclease and/or 3' end pre-mRNA endonuclease can be used to enhance the expression of a recombinant protein in a cell.

The structure of the compounds identified in the assays described herein that modulate the expression of a component of a complex of the invention, the formation of a complex of the invention, the nucleolytic activity of a complex of the invention (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention) can be determined utilizing assays well-known to one of skill in the art or described herein. The methods used will depend, in part, on the nature of the library screened. For example, assays or microarrays of compounds, each having an address or identifier, may be deconvoluted, *e.g.*, by cross-referencing the positive sample to an original compound list that was applied to the individual test assays. Alternatively, the structure of the compounds identified herein may be determined using mass spectrometry, nuclear magnetic resonance ("NMR"), circular dichroism, X ray crystallography, or vibrational spectroscopy.

The invention encompasses the use of the compounds that inhibit or reduce the expression of a component of a complex of the invention, the formation of a complex of the invention, the RNA-nucleolytic activity of a complex of the invention (the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention) for treatment, management or amelioration of a proliferative disorder or a symptom thereof, or a disorder characterized by, associated with or caused by increased RNA-nucleolytic activity (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-



mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention) or a symptom thereof. The invention also encompasses the use of compounds that stimulate or enhance the expression of a component of a complex of the invention, the formation of a complex of the invention, the RNA-nucleolytic activity of a complex of the invention (the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention) for treatment, management or amelioration of a disorder characterized by, associated with or caused by decreased RNA-nucleolytic activity (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention) or a symptom thereof. The invention also encompasses the use of the compounds that stimulate or enhance the expression of a component of a complex of the invention, the formation of a complex of the invention, the nucleolytic activity of a complex of the invention, (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention) for augmenting wound healing in a subject.

The invention provides compositions comprising a carrier and one of the following or a combination of two or more of the following: (i) a component of a complex of the invention; (ii) a complex of the invention, (iii) an antibody or a fragment thereof that immunospecifically binds to a component of a complex of the invention, or a complex of the invention, (iv) a compound that modulates the expression of a component of a complex of the invention, (v) a compound that modulates the formation of a complex of the invention, (vi) a compound that modulates the endonuclease activity (*e.g.*, tRNA splicing endonuclease activity and/or 3' end pre-mRNA endonuclease activity) of a complex of the invention, (vii) a compound that modulates the pre-tRNA cleavage activity of a complex of the invention, and/or (viii) a compound that modulates pre-ribosomal RNA cleavage activity of a complex of the invention. The compositions may further comprise one or more other prophylactic or therapeutic agents. In a preferred embodiment, the compositions are pharmaceutical compositions. In accordance with this intended method of administration or use. The invention encompasses the use of the compositions of the invention in the prevention, treatment, management or amelioration of a

disorder described herein or a symptom thereof.

The invention also provides methods for detecting, diagnosing or monitoring a proliferative disorder or a disorder associated with, characterized by or caused by abnormal pre-tRNA processing and/or 3' end pre-mRNA processing utilizing an antibody that

5 immunospecifically binds to a complex of the invention or a component thereof, or a compound identified in accordance with the methods of the invention that specifically binds to a complex of the invention or a component thereof. The invention also provides methods for detecting, diagnosing or monitoring a proliferative disorder or a disorder associated with, characterized by or caused by abnormal pre-tRNA processing and/or 3' end pre-mRNA processing by comparing

10 the RNA-nucleolytic activity of a complex purified from cells or a tissue sample from a subject with such a disorder or suspected of having such disorder to the RNA-nucleolytic activity of a control, *e.g.*, a complex purified from normal, non-cancerous cells or a tissue sample, using an assay well-known to one of skill in the art or described herein. The invention further provides methods for detecting, diagnosing or monitoring a proliferative disorder or a disorder associated

15 with, characterized by or caused by abnormal pre-tRNA processing and/or 3' end pre-mRNA processing by comparing the structure of a complex of the invention purified from cells or a tissue sample from a subject (*e.g.*, a subject with such a disorder or suspected of having such a disorder) to the structure of a control, *e.g.*, a complex of the invention purified from normal, non-cancerous cells or a tissue sample, using an assay well-known to one of skill in the art (*e.g.*,

20 circular circular dichroism and nuclear magnetic resonance).

The invention also provides a method for modifying protein expression in a cell, the method comprising expressing in the cell at least one component of a complex of the invention. In more specific embodiments, all components of a complex of the invention and/or a fusion complex of the invention are expressed in a cell using recombinant DNA technology. The

25 component or the complex can be expressed using an inducible, a constitutive or a tissue-specific promoter, *e.g.*, a promoter that supports the overexpression of the component or the complex. In certain embodiments, the component of the complex or the fusion complex is mutated to be more active or less active (*i.e.*, has a higher or lower, respectively, complex-forming activity, or has a higher or lower, respectively, RNA-nucleolytic activity) than the wild-

30 type component or complex.

In certain embodiments of the invention, a complex of the invention is used to cleave an mRNA or pre-mRNA molecule containing a pre-mature stop codon. In certain, more specific, embodiments of the invention, a complex of the invention is used to cleave an mRNA or pre-

mRNA molecule at or in the vicinity of a pre-mature stop codon. Without being bound by theory, a complex of the invention cleaves an mRNA or a pre-mRNA molecule at or in the vicinity of a pre-mature stop codon. In certain embodiments, the complex of the invention cleaves an mRNA or a pre-mRNA molecule within 500, 400, 300, 200, 100 or 50 nucleotides of the pre-mature stop codon. In certain embodiments, the complex of the invention cleaves an mRNA or a pre-mRNA molecule within 1 to 50, 1 to 100, 1 to 250, 1 to 500, 10 to 50, 10 to 100, 25 to 100, 50 to 100, 50 to 250, 50 to 500, 100 to 500, or 250 to 500 nucleotides of the pre-mature stop codon.

In certain embodiments of the invention, a complex of the invention is used to identify pre-mature stop codons in an mRNA or pre-mRNA molecule. In certain embodiments, the complex of the invention cleaves an mRNA or a pre-mRNA molecule within 500, 400, 300, 200, 100 or 50 nucleotides of the pre-mature stop codon. In certain embodiments, the complex of the invention cleaves an mRNA or a pre-mRNA molecule within 1 to 50, 1 to 100, 1 to 250, 1 to 500, 10 to 50, 10 to 100, 25 to 100, 50 to 100, 50 to 250, 50 to 500, 100 to 500, or 250 to 500 nucleotides of the pre-mature stop codon.

To identify the pre-mature stop codon, an mRNA or pre-mRNA of interest is incubated with a complex of the invention under conditions conducive to cleavage of the mRNA or pre-mRNA by the complex. Once cleavage occurred, the cleavage products are analyzed to determine the location of the cleavage site. The location of the cleavage site can be determined by any method known to the skilled artisan, such as, but not limited to Northern blot analysis.

In certain embodiments, the complexes of the invention can be used to identify modulators of cleavage of pre-mature stop codons by a complex of the invention. In certain embodiments, a complex of the invention is incubated with an mRNA or pre-mRNA of interest under conditions conducive to cleavage of the mRNA or pre-mRNA by the complex in the presence of a compound, wherein the mRNA or pre-mRNA is known to have a pre-mature stop codon. If the compound increases the amount of cleavage product generated, the compound is identified as an activator of the pre-mature stop codon cleavage activity of a complex of the invention. If the compound decreases the amount of cleavage product generated, the compound is identified as an inhibitor of the pre-mature stop codon cleavage activity of a complex of the invention.

A method of identifying a compound that modulates the stability of a complex, wherein the method comprises the following steps (a) incubating a complex of the invention in the presence of a compound under conditions conducive to maintaining the complex; and (b) determining the amount of the complex, wherein a difference in the amount of the complex

determined in step (b) relative to the amount of the complex determined in the absence of the compound indicates that the compound modulates the stability of the complex.

The invention provides a method of identifying a therapeutic agent for the treatment or prevention of cancer, or amelioration of a symptom thereof, said method comprising: contacting  
5 a member of a library of compounds with a cell; measuring the amount of a complex of the invention formed in the cell; wherein if a compound that reduces the amount of the complex relative to the amount of the complex in the absence of said compound, then contacting the compound with a cancer cell or a neoplastic cell and detecting the proliferation of said cancer cell or neoplastic cell, so that if the compound reduces or inhibits the proliferation of the cancer  
10 cell or neoplastic cell, the compound is identified as an antiproliferative compound. The invention further provides a method of identifying a therapeutic agent for the treatment or prevention of cancer, or amelioration of a symptom thereof, said method comprising: contacting a member of a library of compounds with a complex of the invention and a nucleic acid comprising a reporter gene, wherein the reporter gene comprises a tRNA intron and wherein all  
15 factors required for gene expression are present; and detecting the expression of said reporter gene; wherein if a compound reduces the expression of the reporter gene relative to the expression of the reporter gene in the absence of said compound, then contacting the compound with a cancer cell or a neoplastic cell and detecting the proliferation of said cancer cell or neoplastic cell, so that if the compound reduces or inhibits the proliferation of the cancer cell or  
20 neoplastic cell, the compound is identified as an antiproliferative compound. The invention further provides a method of identifying a therapeutic agent for the treatment or prevention of cancer, or amelioration of a symptom thereof, said method comprising: contacting a member of a library of compounds with a complex of the invention and a nucleic acid comprising a reporter gene and a 3' end pre-mRNA cleavage site, wherein the reporter gene is located 3' of the 3' end  
25 pre-mRNA cleavage site and wherein all factors required for gene expression are present; and detecting the expression of said reporter gene; wherein if a compound reduces the expression of the reporter gene relative to the expression of the reporter gene in the absence of said compound, then contacting the compound with a cancer cell or a neoplastic cell and detecting the proliferation of said cancer cell or neoplastic cell, so that if the compound reduces or inhibits the  
30 proliferation of the cancer cell or neoplastic cell, the compound is identified as an antiproliferative compound. The method may further comprise testing said compound in an animal model for cancer, wherein said testing comprises administering said compound to said animal model and verifying that the compound is effective in reducing the proliferation or spread of cancer cells in said animal model. The method may further comprise determining the

cytotoxic activity of the compound. The method may further comprise determining the cytostatic activity of the compound.

### 3.1 Terminology

5 As used herein, the terms “antibody” and “antibodies” refer to monoclonal antibodies, multispecific antibodies, human antibodies, humanized antibodies, camelised antibodies, chimeric antibodies, single-chain Fvs (scFv), single chain antibodies, single domain antibodies, Fab fragments, F(ab) fragments, disulfide-linked Fvs (sdFv), and anti-idiotypic (anti-Id) antibodies, and epitope-binding fragments of any of the above. In particular, antibodies include  
10 immunoglobulin molecules and immunologically active fragments of immunoglobulin molecules, *i.e.*, molecules that contain an antigen binding site. Immunoglobulin molecules can be of any type (*e.g.*, IgG, IgE, IgM, IgD, IgA and IgY), class (*e.g.*, IgG<sub>1</sub>, IgG<sub>2</sub>, IgG<sub>3</sub>, IgG<sub>4</sub>, IgA<sub>1</sub> and IgA<sub>2</sub>) or subclass.

As used herein, the term “compound” refers to any agent or complex that is being tested  
15 for its ability to modulate the RNA-nucleolytic activity of a complex of the invention (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention), has been identified as modulating RNA-nucleolytic activity of a complex of the invention, has been identified as modulating the formation of a  
20 complex of the invention, or has been identified as modulating the expression of a component of a complex of the invention. The term “compound” includes, but is not limited to, small molecules, antibodies and fragments thereof, and double-stranded and single-stranded nucleic acids. The RNA-nucleolytic activity of a complex of the invention can be, *inter alia*, tRNA splicing endonuclease, 3' end pre-mRNA cleavage endonuclease, pre-tRNA cleavage, or rRNA  
25 cleavage.

As used herein, the term “derivative” in the context of proteinaceous agent (*e.g.*, proteins, polypeptides, peptides, and antibodies) refers to a proteinaceous agent that comprises an amino acid sequence which has been altered by the introduction of amino acid residue substitutions, deletions, and/or additions. The term “derivative” as used herein also refers to a  
30 proteinaceous agent which has been modified, *i.e.*, by the covalent attachment of any type of molecule to the proteinaceous agent. For example, but not by way of limitation, an antibody may be modified, *e.g.*, by glycosylation, acetylation, pegylation, phosphorylation, amidation, derivatization by known protecting/blocking groups, proteolytic cleavage, linkage to a cellular

ligand or other protein, etc. A derivative of a proteinaceous agent may be produced by chemical modifications using techniques known to those of skill in the art, including, but not limited to specific chemical cleavage, acetylation, formylation, metabolic synthesis in the presence of tunicamycin, etc. Further, a derivative of a proteinaceous agent may contain one or  
5 more non-classical amino acids. A derivative of a proteinaceous agent possesses a similar or identical function as the proteinaceous agent from which it was derived, *e.g.*, participates in a complex with RNA-nucleolytic activity. The term "derivative" in the context of a proteinaceous agent also refers to a proteinaceous agent that possesses a similar or identical function as a second proteinaceous agent (*i.e.*, the proteinaceous agent from which the derivative was  
10 derived) but does not necessarily comprise a similar or identical amino acid sequence of the second proteinaceous agent, or possess a similar or identical structure of the second proteinaceous agent. A proteinaceous agent that has a similar amino acid sequence refers to a second proteinaceous agent that satisfies at least one of the following: (a) a proteinaceous agent having an amino acid sequence that is at least 30%, at least 35%, at least 40%, at least 45%, at  
15 least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95% or at least 99% identical to the amino acid sequence of a second proteinaceous agent; (b) a proteinaceous agent encoded by a nucleotide sequence that hybridizes under stringent conditions to a nucleotide sequence encoding a second proteinaceous agent of at least 5 contiguous amino acid residues, at least 10 contiguous amino acid residues, at  
20 least 15 contiguous amino acid residues, at least 20 contiguous amino acid residues, at least 25 contiguous amino acid residues, at least 40 contiguous amino acid residues, at least 50 contiguous amino acid residues, at least 60 contiguous amino residues, at least 70 contiguous amino acid residues, at least 80 contiguous amino acid residues, at least 90 contiguous amino acid residues, at least 100 contiguous amino acid residues, at least 125 contiguous amino acid  
25 residues, or at least 150 contiguous amino acid residues; and (c) a proteinaceous agent encoded by a nucleotide sequence that is at least 30%, at least 35%, at least 40%, at least 45%, at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95% or at least 99% identical to the nucleotide sequence encoding a second proteinaceous agent. A proteinaceous agent with similar structure to a second  
30 proteinaceous agent refers to a proteinaceous agent that has a similar secondary, tertiary or quaternary structure to the second proteinaceous agent. The structure of a proteinaceous agent can be determined by methods known to those skilled in the art, including but not limited to, peptide sequencing, X-ray crystallography, nuclear magnetic resonance, circular dichroism, and

crystallographic electron microscopy. In a specific embodiment, a derivative is a functionally active derivative.

To determine the percent identity of the amino acid sequence of a derivative to the amino acid sequence of the proteinaceous agent from which the derivative is derived or to compare the nucleic acid sequences encoding the derivative and the proteinaceous agent from which the derivative is derived, the sequences are aligned for optimal comparison purposes (*e.g.*, gaps can be introduced in the sequence of a first amino acid or nucleic acid sequence for optimal alignment with a second amino acid or nucleic acid sequence). The amino acid residues or nucleotides at corresponding amino acid positions or nucleotide positions are then compared.

When a position in the first sequence is occupied by the same amino acid residue or nucleotide as the corresponding position in the second sequence, then the molecules are identical at that position. The percent identity between the two sequences is a function of the number of identical positions shared by the sequences (*i.e.*, % identity = number of identical overlapping positions/total number of positions x 100%). In one embodiment, the two sequences are the same length. The determination of percent identity between two sequences can also be accomplished using a mathematical algorithm. A preferred, non-limiting example of a mathematical algorithm utilized for the comparison of two sequences is the algorithm of Karlin and Altschul, 1990, Proc. Natl. Acad. Sci. U.S.A. 87:2264-2268, modified as in Karlin and Altschul, 1993, Proc. Natl. Acad. Sci. U.S.A. 90:5873-5877. Such an algorithm is incorporated into the NBLAST and XBLAST programs of Altschul *et al.*, 1990, J. Mol. Biol. 215:403. BLAST nucleotide searches can be performed with the NBLAST nucleotide program parameters set, *e.g.*, for score=100, wordlength=12 to obtain nucleotide sequences homologous to a nucleic acid molecules of the present invention. BLAST protein searches can be performed with the XBLAST program parameters set, *e.g.*, to score=50, wordlength=3 to obtain amino acid sequences homologous to a protein molecule of the present invention. To obtain gapped alignments for comparison purposes, Gapped BLAST can be utilized as described in Altschul *et al.*, 1997, Nucleic Acids Res. 25:3389-3402. Alternatively, PSI-BLAST can be used to perform an iterated search which detects distant relationships between molecules (*Id.*). When utilizing BLAST, Gapped BLAST, and PSI-Blast programs, the default parameters of the respective programs (*e.g.*, of XBLAST and NBLAST) can be used (see, *e.g.*, the NCBI website). Another preferred, non-limiting example of a mathematical algorithm utilized for the comparison of sequences is the algorithm of Myers and Miller, 1988, CABIOS 4:11-17. Such an algorithm is incorporated in the ALIGN program (version 2.0) which is part of the GCG sequence alignment

software package. When utilizing the ALIGN program for comparing amino acid sequences, a PAM120 weight residue table, a gap length penalty of 12, and a gap penalty of 4 can be used.

The percent identity between two sequences can be determined using techniques similar to those described above, with or without allowing gaps. In calculating percent identity,

5 typically only exact matches are counted.

As used herein, the terms "disorder" and "disease" are to refer to a condition in a subject (*e.g.*, a proliferative disorder or a disorder characterized by, associated with or caused by abnormal RNA-nucleolytic activity).

As used herein, the term "effective amount" in the context of a proliferative disorder  
10 refers to the amount of a therapy (*e.g.*, a compound, a complex of the invention, a component of a complex of the invention, a nucleic acid encoding a component of a complex of the invention, a nucleic acid that inhibits the expression of a component of a complex of the invention, an antibody or a fragment thereof that immunospecifically binds to a complex of the invention, or an antibody or a fragment thereof that immunospecifically binds to a component of a complex of  
15 the invention), which is sufficient to reduce or ameliorate the progression, severity and/or duration of a proliferative disorder or one or more symptoms thereof, prevent the development, recurrence or onset of a proliferative disorder or one or more symptoms thereof, prevent the advancement of a proliferative disorder or one or more symptoms thereof, or enhance or improve the therapeutic(s) effect(s) of another therapy. An "effective amount" in the context of  
20 a disorder characterized by, associated with or caused by abnormal RNA-nucleolytic activity refers to the amount of a therapy (*e.g.*, a compound, a complex of the invention, a component of a complex of the invention, a nucleic acid encoding a component of a complex of the invention, a nucleic acid that inhibits the expression of a component of a complex of the invention, an antibody or a fragment thereof that immunospecifically binds to a complex of the invention, or  
25 an antibody or a fragment thereof that immunospecifically binds to a component of a complex of the invention), which is sufficient to reduce or ameliorate the progression, severity and/or duration of a disorder characterized by, associated with or caused by abnormal RNA-nucleolytic activity or one or more symptoms thereof, prevent the development, recurrence or onset of a disorder characterized by, associated with or caused by abnormal RNA-nucleolytic activity or  
30 one or more symptoms thereof, prevent the advancement of a disorder characterized by, associated with or caused by abnormal RNA-nucleolytic activity or one or more symptoms thereof, or enhance or improve the therapeutic(s) effect(s) of another therapy. As used herein, the term "effective amount" in the context of wound healing refers to the amount of a therapy (*e.g.*, a compound, a complex of the invention, a component of a complex of the invention, a



nucleic acid encoding a component of a complex of the invention, a nucleic acid that inhibits the expression of a component of a complex of the invention, an antibody or a fragment thereof that immunospecifically binds to a complex of the invention, or an antibody or a fragment thereof that immunospecifically binds to a component of a complex of the invention), which is sufficient to reduce or ameliorate the progression, severity and/or duration of a wound (*e.g.*, a wound caused by an injury) or one or more symptoms thereof, prevent the development, recurrence or onset of a wound, a condition associated with a wound, or one or more symptoms thereof, prevent the advancement of a condition associated with a wound or one or more symptoms thereof, or enhance or improve the therapeutic(s) effect(s) of another therapy.

10           As used herein, the term "fluorescent acceptor moiety" refers to a fluorescent compound that absorbs energy from a fluorescent donor moiety and re-emits the transferred energy as fluorescence. Examples of fluorescent acceptor moieties include, but are not limited to, coumarins and related fluorophores, xanthenes (*e.g.*, fluoresceins, rhodols, and rhodamines), resorufins, cyanines, difluoroboradiazindacenes and phthalocyanines.

15           As used herein, the term "fluorescent donor moiety" refers to a fluorescent compound that can absorb energy and is capable of transferring the energy to an acceptor, such as another fluorescent compound. Examples of fluorescent donor moieties include, but are not limited to, coumarins and related dyes, xanthene dyes (*e.g.*, fluoresceins, rhodols and rhodamines), resorufins, cyanine dyes, bimanes, acridines, isoindoles, dansyl dyes, aminophthalic hydrazides  
20 (*e.g.*, luminol and isoluminol derivatives), aminophthalimides, aminonaphthalimides, aminobenzofurans, aminoquinolines, dicyanohydroquinones, fluorescent europium, terbium complexes and related compounds.

          As used herein, the term "fluorophore" refers to a chromophore that fluoresces.

          As used herein, the term "fragment" refers to a peptide or polypeptide comprising an  
25 amino acid sequence of at least 5 contiguous amino acid residues, at least 10 contiguous amino acid residues, at least 15 contiguous amino acid residues, at least 20 contiguous amino acid residues, at least 25 contiguous amino acid residues, at least 40 contiguous amino acid residues, at least 50 contiguous amino acid residues, at least 60 contiguous amino residues, at least 70 contiguous amino acid residues, at least contiguous 80 amino acid residues, at least contiguous  
30 90 amino acid residues, at least contiguous 100 amino acid residues, at least contiguous 125 amino acid residues, at least 150 contiguous amino acid residues, at least contiguous 175 amino acid residues, at least contiguous 200 amino acid residues, or at least contiguous 250 amino acid residues of the amino acid sequence of another polypeptide or protein. In a specific

embodiment, a fragment of a protein or polypeptide retains at least one function of the protein or polypeptide.

As used herein, the term "functionally active derivative" in the context of proteinaceous agent is a derivative of a proteinaceous agent that retains at least one function of the polypeptide or protein from which the derivative is derived. In a specific embodiment, a functionally active derivative retains at least two, three, four, or five functions of the protein or polypeptide from which the derivative is derived. In a specific embodiment, the functionally active derivative retains the ability of the protein from which it is derived to bind to a specific third protein or form a specific complex with RNA-nucleolytic activity, *e.g.*, a complex of the invention. In another specific embodiment, the functionally active derivative retains the RNA-nucleolytic activity of protein from which the derivative is derived.

As used herein, the term "functionally active fragment" refers to a fragment of a polypeptide or protein that retains at least one function of the second, different polypeptide or protein. In a specific embodiment, a fragment of a polypeptide or protein retains at least two, three, four, or five functions of the protein or polypeptide. In a specific embodiment, the functionally active fragment retains the ability of the second protein to bind to a specific third protein or form a specific complex. In another specific embodiment, the functionally active fragment retains the RNA-nucleolytic activity of the second protein.

As used herein, the term "fusion complex" means a protein complex, wherein the protein components of the complex are linked to each other via a peptide bond or other covalent linkage.

As used herein, the term "fusion protein" refers to a polypeptide or protein that comprises an amino acid sequence of a first protein or polypeptide or functional fragment, analog or derivative thereof, and an amino acid sequence of a heterologous protein, polypeptide, or peptide (*i.e.*, a second protein or polypeptide or fragment, analog or derivative thereof) different than the first protein or fragment, analog or derivative thereof). In other words, a fusion protein comprises an amino acid sequence of a first protein, polypeptide or peptide and an amino acid sequence that is not normally associated with or a part of the first protein.

As used herein, the term "host cell" includes a particular subject cell transfected or transformed with a nucleic acid molecule and the progeny or potential progeny of such a cell. Progeny of such a cell may not be identical to the parent cell transfected with the nucleic acid molecule due to mutations or environmental influences that may occur in succeeding generations or integration of the nucleic acid molecule into the host cell genome.

As used herein, the term "hybridizes under stringent conditions" describes conditions for

hybridization and washing under which nucleotide sequences at least 30% (preferably, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, 98%, 99% or 99.5%) identical to each other typically remain hybridized to each other. Such stringent conditions are known to those skilled in the art and can be found in *Current Protocols in Molecular Biology*,  
5 John Wiley & Sons, N.Y. (1989), 6.3.1-6.3.6. In one, non-limiting example stringent hybridization conditions are hybridization at 6X sodium chloride/sodium citrate (SSC) at about 45°C, followed by one or more washes in 0.1XSSC, 0.2% SDS at about 68 C. In a preferred, non-limiting example stringent hybridization conditions are hybridization in 6XSSC at about 45°C, followed by one or more washes in 0.2 X SSC, 0.1% SDS at 50-65°C (*i.e.*, one or more  
10 washes at 50°C, 55°C, 60°C or 65°C). It is understood that the nucleic acids of the invention do not include nucleic acid molecules that hybridize under these conditions solely to a nucleotide sequence consisting of only A or T nucleotides. In a specific embodiment, high stringency conditions comprise hybridization in a buffer consisting of 6X SSC, 50 mM Tris-HCl (pH=7.5), 1 mM EDTA, 0.02% PVP, 0.02% Ficoll, 0.02% BSA and 100 µg/ml denatured salmon sperm  
15 DNA, for 48 hours at 65°C, washing in a buffer consisting of 2X SSC, 0.01% PVP, 0.01% Ficoll and 0.01% BSA, for 45 minutes at 37°C, and washing in a buffer consisting of 0.1X SSC, for 45 minutes at 50°C. For an exemplary method for determining stringency conditions, see section 4.3.1.

As used herein, the term “immunospecifically binds” and analogous terms refer to  
20 peptides, polypeptides, proteins, fusion proteins and antibodies or fragments thereof that specifically bind to an antigen or a fragment and do not specifically bind to other antigens (*e.g.*, as determined via standard immunoassays, such as, but not limited to, an ELISA). A peptide, polypeptide, protein, or antibody that immunospecifically binds to an antigen may bind to other peptides, polypeptides, or proteins with lower affinity as determined by, *e.g.*, immunoassays,  
25 BIAcore, or other assays known in the art. Antibodies or fragments that immunospecifically bind to an antigen may be cross-reactive with related antigens. Preferably, antibodies or fragments that immunospecifically bind to an antigen do not cross-react with other antigens.

As used herein, the term “in combination” refers to the use of more than one therapy (*e.g.*, prophylactic and/or therapeutic agents). The use of the term “in combination” does not  
30 restrict the order in which therapies (*e.g.*, prophylactic and/or therapeutic agents) are administered to a subject with a disorder. A first therapy (*e.g.*, a prophylactic or therapeutic agent such as a compound identified in accordance with the methods of the invention) can be administered prior to (*e.g.*, 5 minutes, 15 minutes, 30 minutes, 45 minutes, 1 hour, 2 hours, 4

hours, 6 hours, 12 hours, 24 hours, 48 hours, 72 hours, 96 hours, 1 week, 2 weeks, 3 weeks, 4 weeks, 5 weeks, 6 weeks, 8 weeks, or 12 weeks before), concomitantly with, or subsequent to (e.g., 5 minutes, 15 minutes, 30 minutes, 45 minutes, 1 hour, 2 hours, 4 hours, 6 hours, 12 hours, 24 hours, 48 hours, 72 hours, 96 hours, 1 week, 2 weeks, 3 weeks, 4 weeks, 5 weeks, 6 weeks, 8 weeks, or 12 weeks after) the administration of a second therapy (e.g., a prophylactic or therapeutic agent such as a chemotherapeutic agent or a TNF- $\alpha$  antagonist) to a subject with a disorder.

As used herein, the term "library" refers to a plurality of compounds. A library can be a combinatorial library, e.g., a collection of compounds synthesized using combinatorial chemistry techniques, or a collection of unique chemicals of low molecular weight (less than 1000 daltons) that each occupy a unique three-dimensional space. In a specific embodiment, a library is composed of at least 50; 100; 150; 200; 250; 500; 750; 1,000; 1,250; 1,500; 1,750; 2,000; 2,500; 5,000; 7,500; 10,000; 20,000; 30,000; 40,000; or at least 50,000 different compounds. In a specific embodiment, a library is composed of at most 50; 100; 150; 200; 250; 500; 750; 1,000; 1,250; 1,500; 1,750; 2,000; 2,500; 5,000; 7,500; 10,000; 20,000; 30,000; 40,000; or at most 50,000 different compounds. In a specific embodiment, a library is composed of between 10 and 100; 10 and 150; 100 and 200; 100 and 250; 100 and 500; 100 and 750; 500 and 1,000; 500 and 1,250; 500 and 1,500; 500 and 1,750; 1,000 and 2,000; 1,000 and 2,500; 2,000 and 5,000; 2,000 and 7,500; 2,000 and 10,000; 5,000 and 20,000; 10,000 and 30,000; 10,000 and 40,000; between 20,000 and 50,000 different compounds.

As used herein, the terms "manage", "managing" and "management" refer to the beneficial effects that a subject derives from a therapy (e.g., administration of a prophylactic or therapeutic agent) which does not result in a cure of the disorder. In certain embodiments, a subject is administered one or more therapies to "manage" a disease or disorder so as to prevent the progression or worsening of the disease or disorder.

As used herein, the terms "non-responsive" and refractory" describe patients treated with a currently available therapy (e.g., prophylactic or therapeutic agent) for a disorder (e.g., cancer), which is not clinically adequate to relieve the disorder or one or more symptoms associated with such disorder. Typically, such patients suffer from severe, persistently active disease and require additional therapy to ameliorate the symptoms associated with their disorder.

As used herein, the term "ORF" refers to the open reading frame of a mRNA, i.e., the region of the mRNA that is translated into protein.

As used herein, the phrase "pharmaceutically acceptable salt(s)," includes, but is not

limited to, salts of acidic or basic groups that may be present in compounds identified using the methods of the present invention. Compounds that are basic in nature are capable of forming a wide variety of salts with various inorganic and organic acids. The acids that can be used to prepare pharmaceutically acceptable acid addition salts of such basic compounds are those that

5 form non-toxic acid addition salts, i.e., salts containing pharmacologically acceptable anions, including but not limited to sulfuric, citric, maleic, acetic, oxalic, hydrochloride, hydrobromide, hydroiodide, nitrate, sulfate, bisulfate, phosphate, acid phosphate, isonicotinate, acetate, lactate, salicylate, citrate, acid citrate, tartrate, oleate, tannate, pantothenate, bitartrate, ascorbate, succinate, maleate, gentisinate, fumarate, gluconate, glucaronate, saccharate, formate, benzoate,

10 glutamate, methanesulfonate, ethanesulfonate, benzenesulfonate, p-toluenesulfonate and pamoate (i.e., 1,1'-methylene-bis-(2-hydroxy-3-naphthoate)) salts. Compounds that include an amino moiety may form pharmaceutically acceptable salts with various amino acids, in addition to the acids mentioned above. Compounds that are acidic in nature are capable of forming base salts with various pharmacologically acceptable cations. Examples of such salts include alkali

15 metal or alkaline earth metal salts and, particularly, calcium, magnesium, sodium lithium, zinc, potassium, and iron salts.

As used herein, the terms "prevent", "preventing" and "prevention" refer to the prevention of the development, recurrence or onset of a disorder or one or more symptoms thereof resulting from the administration of a therapy or the administration of a combination of

20 therapies.

As used herein, the term "previously determined reference range" refers to a reference range for the readout of a particular assay. In a specific embodiment, the term refers to a reference range for the expression and/or the activity of a reporter gene by a particular cell or in a particular cell-free extract. Each laboratory will establish its own reference range for each

25 particular assay, each cell type and each cell-free extract. In a preferred embodiment, at least one positive control and at least one negative control are included in each batch of compounds analyzed.

As used herein, the terms "prophylactic agent" and "prophylactic agents" refer to any agent(s) which can be used in the prevention of a disorder. In certain embodiments, the term

30 "prophylactic agent" refers to a compound identified in the screening assays described herein, a complex of the invention, an antibody or a fragment thereof that immunospecifically binds to a complex of the invention, Sen2ΔEx8 protein, a nucleic acid encoding Sen2ΔEx8, an antibody or a fragment thereof that immunospecifically binds to Sen2ΔEx8, a component of a complex of

the invention or a nucleic acid encoding a component of a complex of the invention or a nucleic acid that prevents or reduces the expression of a component of a complex of the invention (*e.g.*, an antisense nucleic acid or using RNAi). In certain other embodiments, the term “prophylactic agent” refers to an agent other than a compound identified in the screening assays described

5 herein, a complex of the invention, an antibody or a fragment thereof that immunospecifically binds to a complex of the invention, Sen2ΔEx8 protein, a nucleic acid encoding Sen2ΔEx8, an antibody or a fragment thereof that immunospecifically binds to Sen2ΔEx8, a component of a complex of the invention or a nucleic acid encoding a component of a complex of the invention or a nucleic acid that prevents or reduces the expression of a component of a complex of the

10 invention (*e.g.*, an antisense nucleic acid or using RNAi), which is known to be useful for, or has been or is currently being used to prevent or impede the onset, development and/or progression of a disorder or one or more symptoms thereof. A “prophylactic agent” in the context of a disorder characterized by, associated with or caused by abnormal RNA-nucleolytic activity refers to the amount of a compound, a complex of the invention, a component of a complex of

15 the invention, a nucleic acid encoding a component of a complex of the invention, a nucleic acid that inhibits the expression of a component of a complex of the invention, an antibody or a fragment thereof that immunospecifically binds to a complex of the invention, or an antibody or a fragment thereof that immunospecifically binds to a component of a complex of the invention, which can prevent or reduce the risk of a disorder characterized by, associated with or caused by

20 abnormal RNA-nucleolytic activity or one or more symptoms thereof. As used herein, the term “prophylactic agent” in the context of wound healing refers to a compound, a complex of the invention, a component of a complex of the invention, a nucleic acid encoding a component of a complex of the invention, a nucleic acid that inhibits the expression of a component of a complex of the invention, an antibody or a fragment thereof that immunospecifically binds to a

25 complex of the invention, or an antibody or a fragment thereof that immunospecifically binds to a component of a complex of the invention, which can prevent the development, recurrence or onset of a wound, a condition associated with a wound, or one or more symptoms thereof, prevent the advancement of a condition associated with a wound or one or more symptoms thereof, or enhance or improve the therapeutic(s) effect(s) of another therapy.

30 As used herein, the phrase “prophylactically effective amount” refers to the amount of a therapy (*e.g.*, a prophylactic agent, such as a compound identified by the methods of the invention, a complex of the invention, a component of a complex of the invention, a nucleic acid encoding a component of a complex of the invention, a nucleic acid that inhibits the expression

of a component of a complex of the invention, an antibody or a fragment thereof that immunospecifically binds to a complex of the invention, or an antibody or a fragment thereof that immunospecifically binds to a component of a complex of the invention) which is sufficient to result in the prevention of the development, recurrence or onset of a disorder or one or more symptoms thereof.

As used herein, the term "purified" in the context of a compound other than a proteinaceous agent or a nucleic acid, *e.g.*, a compound identified in accordance with the method of the invention, refers to a compound that is substantially free of chemical precursors or other chemicals when chemically synthesized. In a specific embodiment, the compound is 60%, preferably 65%, 70%, 75%, 80%, 85%, 90%, or 99% free of other, different compounds. In a preferred embodiment, a compound identified in accordance with the methods of the invention is purified.

Specifically, the term "purified," in the context of a proteinaceous agent (*e.g.*, a peptide, polypeptide, or protein, such as a tRNA splicing endonuclease or subunit thereof) refers to a proteinaceous agent which is substantially free of cellular material or contaminating proteins from the cell or tissue source from which it is derived, or substantially free of chemical precursors or other chemicals when chemically synthesized. The language "substantially free of cellular material" includes preparations of a proteinaceous agent in which the proteinaceous agent is separated from cellular components of the cells from which it is purified or recombinantly produced. Thus, a proteinaceous agent or an agent that is substantially free of cellular material includes preparations of a proteinaceous agent having less than about 30%, 20%, 10%, or 5% (by dry weight) of heterologous protein, polypeptide, peptide, or antibody (also referred to as a "contaminating protein"). When the proteinaceous agent is recombinantly produced, it is also preferably substantially free of culture medium, *i.e.*, culture medium represents less than about 20%, 10%, or 5% of the volume of the protein preparation. When the proteinaceous agent is produced by chemical synthesis, it is preferably substantially free of chemical precursors or other chemicals, *i.e.*, it is separated from chemical precursors or other chemicals which are involved in the synthesis of the proteinaceous agent. Accordingly, such preparations of a proteinaceous agent have less than about 30%, 20%, 10%, 5% (by dry weight) of chemical precursors or compounds other than the proteinaceous agent of interest. Preferably, proteinaceous agents disclosed herein are purified.

As used herein, the term "purified" in the context of nucleic acid molecules refers to a nucleic acid molecule which is separated from other nucleic acid molecules which are present in

the natural source of the nucleic acid molecule. Moreover, a "purified" nucleic acid molecule, such as a cDNA molecule, is preferably substantially free of other cellular material, or culture medium when produced by recombinant techniques, or substantially free of chemical precursors or other chemicals when chemically synthesized. In a specific embodiment, nucleic acid  
5 molecules are purified. In a preferred embodiment, a nucleic acid molecule encoding a component of a complex of the invention is purified.

As used herein, the term "quencher" refers to a molecule or a part of a compound that is capable of reducing the emission from a fluorescent moiety. Such reduction includes reducing the light after the time when a photon is normally emitted from a fluorescent moiety.

10 As used herein, "RNA-nucleolytic activity" refers to, but is not limited to, pre-tRNA splicing activity, 3' end pre-mRNA endonuclease activity, pre-tRNA cleavage activity and pre-ribosomal RNA cleavage activity.

As used herein, the term "small molecules" and analogous terms include, but are not limited to, peptides, peptidomimetics, amino acids, amino acid analogs, polynucleotides,  
15 polynucleotide analogs, nucleotides, nucleotide analogs, organic or inorganic compounds (*i.e.*, including heteroorganic and organometallic compounds) having a molecular weight less than about 10,000 grams per mole, organic or inorganic compounds having a molecular weight less than about 5,000 grams per mole, organic or inorganic compounds having a molecular weight less than about 1,000 grams per mole, organic or inorganic compounds having a molecular  
20 weight less than about 500 grams per mole, organic or inorganic compounds having a molecular weight less than about 100 grams per mole, and salts, esters, and other pharmaceutically acceptable forms of such compounds. Salts, esters, and other pharmaceutically acceptable forms of such compounds are also encompassed.

As used herein, the term "specifically binds" and analogous terms in the context of  
25 compounds identified in accordance with the invention refers to refer compounds identified in accordance with the invention that bind to a complex of the invention or a protein component of a complex of the invention or a fragment of a protein component of a complex of the invention and do not bind to, or bind with lower affinity to, other complexes, proteins or polypeptides. The binding affinity can be determined by, *e.g.*, immunoassays, BIAcore, or other assays known  
30 in the art. Compounds that specifically bind to a complex of the invention or a protein component of a complex of the invention or a fragment of a protein component of a complex of the invention may be cross-reactive with related proteins or polypeptides. Preferably, compounds that specifically bind to a complex of the invention or a protein component of a



complex of the invention or a fragment of a protein component of a complex of the invention are not cross-reactive with related proteins or polypeptides.

As used herein, the terms "subject" and "patient" are used interchangeably herein. The terms "subject" and "subjects" refer to an animal, preferably a mammal including a non-primate (e.g., a cow, pig, horse, cat, dog, rat, and mouse) and a primate (e.g., a chimpanzee, a monkey such as a cynomolgous monkey, and a human), and more preferably a human. In one embodiment, the subject is refractory or non-responsive to current therapies for a proliferative disorder. In another embodiment, the subject is a farm animal (e.g., a horse, a cow, a pig, etc.) or a pet (e.g., a dog or a cat). In a preferred embodiment, the subject is a human.

As used herein, the phrase "a substrate for a human tRNA splicing endonuclease" refers to any nucleotide sequence recognized and excised by a human tRNA splicing endonuclease. For example, a nucleotide sequence comprising a bulge-helix-bulge structure or a mature domain of a precursor tRNA may be utilized as a substrate for a human tRNA splicing endonuclease in an assay described herein. A nucleotide sequence recognized and excised by a human tRNA splicing endonuclease may comprise 10 nucleotides, 15 nucleotides, 20 nucleotides, 25 nucleotides, 30 nucleotides, 40 nucleotides, 45 nucleotides, 50 nucleotides, 55 nucleotides, 60 nucleotides, 65 nucleotides, 75 nucleotides, 100 nucleotides, 125 nucleotides, 150 nucleotides, or more. In a specific embodiment, the substrates for a tRNA splicing endonuclease utilized in the assays described herein comprise a tRNA intron. The substrate may comprise a mature domain or a bulge-helix-bulge conformation. In a preferred embodiment, the substrate comprises a mature domain of a precursor tRNA.

A substrate for a human tRNA endonuclease may be produced by any method well-known to one of skill in the art. For example, the substrate may be chemically synthesized using phosphoramidite or other solution or solid-phase methods. Detailed descriptions of the chemistry used to form polynucleotides by the phosphoramidite method are well known (*see, e.g., Caruthers et al., U.S. Pat. Nos. 4,458,066 and 4,415,732; Caruthers et al., 1982, Genetic Engineering 4:1-17; Users Manual Model 392 and 394 Polynucleotide Synthesizers, 1990, pages 6-1 through 6-22, Applied Biosystems, Part No. 901237; Ojwang, et al., 1997, Biochemistry, 36:6033-6045*). After synthesis, the substrate can be purified using standard techniques known to those skilled in the art (*see Hwang et al., 1999, Proc. Natl. Acad. Sci. USA 96(23):12997-13002 and references cited therein*). Depending on the length of the substrate and the method of its synthesis, such purification techniques include, but are not limited to, reverse-phase high-performance liquid chromatography ("reverse-phase HPLC"), fast performance liquid

chromatography ("FPLC"), and gel purification. In a specific embodiment, the substrates depicted in Figure 1 are utilized in the assays described herein. To generate the hybridized tRNA substrate depicted in Figure 1, both strands of the hybridized substrate are transcribed separately and the two strands are subsequently hybridized by heating and cooling. For  
5 synthesis of the circularly permuted tRNA substrate, the RNA is transcribed from the 5' end in the intron (see Figure 1C) to the 3' end in the intron.

As used herein, the phrase "a substrate for a human 3' end pre-mRNA endonuclease" refers to any nucleotide sequence recognized and excised by a human 3' end pre-mRNA endonuclease. For example, a nucleotide sequence comprising a hexanucleotide with the  
10 sequence AAUAAA upstream and a G/U-rich sequence element downstream of the cleavage site may be utilized as a substrate for 3' end pre-mRNA endonuclease in an assay described herein. A nucleotide sequence recognized and excised by a 3' end pre-mRNA endonuclease may comprise 10 nucleotides, 15 nucleotides, 20 nucleotides, 25 nucleotides, 25 nucleotides, 30  
15 nucleotides, 40 nucleotides, 45 nucleotides, 50 nucleotides, 55 nucleotides, 60 nucleotides, 65 nucleotides, 75 nucleotides, 100 nucleotides, 125 nucleotides, 150 nucleotides, or more. In a specific embodiment, the substrates for 3' end pre-mRNA endonuclease utilized in the assays described herein comprise a cleavage and polyadenylation site.

As used herein, the term "synergistic" refers to a combination of a compound identified using one of the methods described herein (*i.e.*, that modulates the activity of a complex of the  
20 invention), a complex of the invention, a component of a complex of the invention, an antibody or a fragment thereof that immunospecifically binds to a complex of the invention, an antibody or a fragment thereof that immunospecifically binds to a component of a complex of the invention, or a nucleic acid encoding a component of a complex of the invention, and another  
25 therapy (*e.g.*, agent) which has been or is currently being used to prevent, treat, manage or ameliorate a disorder or a symptom thereof, which is more effective than the additive effects of the therapies. A synergistic effect of a combination of therapies (*e.g.*, prophylactic or  
therapeutic agents) permits the use of lower dosages of one or more of the therapies and/or less frequent administration of said therapies to a subject with a disorder. The ability to utilize lower  
dosages of a therapy (*e.g.*, a prophylactic or therapeutic agent) and/or to administer said therapy  
30 less frequently reduces the toxicity associated with the administration of said agent to a subject without reducing the efficacy of said therapies in the prevention, treatment, management or amelioration of a disorder or a symptom thereof. In addition, a synergistic effect can result in improved efficacy of therapies (*e.g.*, agents) in the prevention, treatment, management or  
amelioration of a disorder or a symptom thereof. Finally, a synergistic effect of a combination

of therapies (*e.g.*, prophylactic or therapeutic agents) may avoid or reduce adverse or unwanted side effects associated with the use of either therapy alone.

As used herein, the terms “therapeutic agent” and “therapeutic agents” refer to any agent(s) which can be used in the prevention, treatment, management or amelioration of a disorder or a symptom thereof. In certain embodiments, the term “therapeutic agent” refers to a compound identified in the screening assays described herein, a complex of the invention, a component of a complex of the invention, an antibody or a fragment thereof that immunospecifically binds to a complex of the invention, an antibody or a fragment thereof that immunospecifically binds to a component of a complex of the invention, or a nucleic acid encoding a component of a complex of the invention or anti-sense or RNAi nucleic acid. In other embodiments, the term “therapeutic agent” refers to an agent other than a compound identified in the screening assays described herein which is known to be useful for, or has been or is currently being used to prevent, treat, manage or ameliorate a disorder or one or more symptoms thereof.

As used herein, the term “therapeutically effective amount” refers to that amount of a therapy (*e.g.*, a therapeutic agent) sufficient to result in the amelioration of one or more symptoms of a disorder, prevent advancement of a disorder, cause regression of the disorder, or to enhance or improve the therapeutic effect(s) of another therapy (*e.g.*, therapeutic agent). In a specific embodiment, with respect to the treatment of cancer, a therapeutically effective amount refers to the amount of a therapy (*e.g.*, a therapeutic agent) that inhibits or reduces the proliferation of cancerous cells, inhibits or reduces the spread of tumor cells (metastasis), inhibits or reduces the onset, development or progression of one or more symptoms associated with cancer, or reduces the size of a tumor. Preferably, a therapeutically effective amount of a therapy (*e.g.*, a therapeutic agent) reduces the proliferation of cancerous cells or the size of a tumor by at least 5%, preferably at least 10%, at least 15%, at least 20%, at least 25%, at least 30%, at least 35%, at least 40%, at least 45%, at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, or at least 100% relative to a control such as phosphate buffered saline (“PBS”). A “therapeutically effective amount” in the context of a disorder characterized by, associated with or caused by abnormal RNA-nucleolytic activity refers to the amount of a compound, a complex of the invention, a component of a complex of the invention, a nucleic acid encoding a component of a complex of the invention, a nucleic acid that inhibits the expression of a component of a complex of the invention, an antibody or a fragment thereof that immunospecifically binds to a complex of the invention, or an antibody or a fragment thereof that immunospecifically binds to a component of

a complex of the invention, which is sufficient to reduce or ameliorate the progression, severity and/or duration of a disorder characterized by, associated with or caused by abnormal RNA-nucleolytic activity or one or more symptoms thereof, prevent the development, recurrence or onset of a disorder characterized by, associated with or caused by abnormal RNA-nucleolytic activity or one or more symptoms thereof, prevent the advancement of a disorder characterized by, associated with or caused by abnormal RNA-nucleolytic activity or one or more symptoms thereof, or enhance or improve the therapeutic(s) effect(s) of another therapy. As used herein, the term "therapeutically effective amount" in the context of wound healing refers to the amount of a compound, a complex of the invention, a component of a complex of the invention, a nucleic acid encoding a component of a complex of the invention, a nucleic acid that inhibits the expression of a component of a complex of the invention, an antibody or a fragment thereof that immunospecifically binds to a complex of the invention, or an antibody or a fragment thereof that immunospecifically binds to a component of a complex of the invention, which is sufficient to reduce or ameliorate the progression, severity and/or duration of a wound (*e.g.*, a wound caused by an injury) or one or more symptoms thereof, prevent the development, recurrence or onset of a wound, a condition associated with a wound, or one or more symptoms thereof, prevent the advancement of a condition associated with a wound or one or more symptoms thereof, or enhance or improve the therapeutic(s) effect(s) of another therapy.

As used herein, the terms "treat", "treatment" and "treating" refer to the reduction or amelioration of the progression, severity and/or duration of a disorder or one or more symptoms thereof resulting from the administration of one or more therapies (*e.g.*, compounds identified in accordance the methods of the invention, a complex of the invention, a component of a complex of the invention, an antibody or a fragment thereof that immunospecifically binds to a complex of the invention, an antibody or a fragment thereof that immunospecifically binds to a component of a complex of the invention, or a nucleic acid encoding a component of a complex of the invention, or a combination thereof and another therapy). In specific embodiments, such terms refer to the inhibition or reduction in the proliferation of cancerous cells, the inhibition or reduction the spread of tumor cells (metastasis), the inhibition or reduction in the onset, development or progression of one or more symptoms associated with cancer, or the reduction in the size of a tumor.

As used herein, the term "tRNA intron" refers to any nucleotide sequence recognized and excised by a human tRNA splicing endonuclease. In particular, the term "tRNA intron" refers to an intron typically found in a precursor tRNA.

As used herein, the term "tRNA splicing endonuclease" refers to the enzyme that is

responsible for the recognition of the splice sites contained in precursor tRNA and the cleavage of the introns present in precursor tRNA. The archaeal tRNA splicing endonuclease recognizes the bulge-helix-bulge motif in archaeal precursor tRNA. The eukaryotic tRNA splicing endonuclease recognizes the splice sites contained in precursor tRNA by measuring the distance from the mature domain to the splice sites. The eukaryotic tRNA splicing endonuclease also has the capacity to recognize a bulge-helix-bulge motif contained in precursor tRNA. The yeast tRNA endonuclease is a heterotetramer comprising subunits having the molecular masses of 54 kDa (SEN54), 44 kDa (SEN2), 34 kDa (SEN 34), and 15 kDa (SEN 15). The human homologs of these factors and their GenBank accession numbers are set forth in Table 1.

As used herein, the terms "therapy" and "therapies" refer to any method, protocol and/or agent that can be used in the prevention, treatment, management or amelioration of a disease or disorder (*e.g.*, a proliferative disorder or a condition associated with wound healing) or one or more symptoms thereof. In certain embodiments, such terms refer to chemotherapy, radiation therapy, surgery, supportive therapy and/or other therapies useful in the prevention, treatment, management or amelioration of a disease or disorder (*e.g.*, a proliferative disorder or a condition associated with wound healing) or one or more symptoms thereof known to skilled medical personnel.

### Abbreviations

CPSF	Cleavage-Polyadenylation Specificity Factor
CFI <sub>m</sub>	Cleavage Factor I <sub>m</sub>
CFII <sub>m</sub>	Cleavage Factor II <sub>m</sub>
CstF or CSTF	Cleavage Stimulation Factor
HTS	High Throughput Screen
FP	fluorescence polarization
FRET	Fluorescence Resonance Energy Transfer
HPLC	high-performance liquid chromatography
FPLC	fast performance liquid chromatography
FACS	Fluorescence activated cell sorter

## 20      **3.2 BRIEF DESCRIPTION OF THE DRAWINGS**

Fig. 1: Substrates for HTS Fluorescent screening. The endogenous tRNA is shown in

panel A; the hybridized tRNA substrate is shown in panel B; and the circularly permuted tRNA substrate is shown in panel C. The 5' ss designates the 5' splice site and 3' ss designates the 3' splice site.

Fig.2: Schematic representation of removal of introns from pre-tRNA in yeast. In yeast tRNA intron removal requires the function of three enzymes. In the first step a tRNA endonuclease recognizes and cleaves the precursor tRNA at the 5' and 3' splice sites. This enzyme is a heterotetramer composed of the Sen54, Sen2, Sen34 and Sen15 proteins. The product 5' and 3' exons are ligated by a tRNA ligase through a series of enzymatic steps which ultimately leads to joining of the two exons with a 2' phosphate at the splice junction. This unusual tRNA intermediate is then processed by a 2' phosphotransferase which transfers the 2' phosphate to an NAD acceptor yielding a mature tRNA.

Fig.3: Schematic Representation of Yeast tRNA Splicing Holoenzyme. Through structural Studies with the Archaeal enzyme and subsequent two-hybrid interaction experiments with the yeast subunits, a model for the interaction of the four subunits of the yeast tRNA endonuclease was proposed (Li et al., 1998 Science 280, 279-284). Dimerization of heterologous subunits Sen54 and Sen15 with active site subunits Sen2 and Sen34 respectively is achieved by the interaction of a conserved Beta sheet at the C-terminus each subunit. The active site containing dimers are then brought together through interaction of the conserved charged Loop L10 with a basic groove formed between the N and Cterminal domains in the two active site containing subunits.

Fig. 4: Model for Cleavage of tRNA by the Yeast tRNA Endonuclease. Cleavage of tRNA occurs through catalysis of the 5' splice site by the active site contained in the Sen2 subunit and the 3' splice site by Sen34.

Fig. 5: Amino Acid Sequence Alignment of human (Hs) Sen2 (SEQ ID NO: 1) and HsSen2 var. (SEQ ID NO: 2)) and the yeast *Saccaromyces cerevisiae* (ScSen2p (SEQ ID NO: 3)) tRNA splicing endonuclease Sen2 subunit. The boxed amino acid residues indicate the YRGGY (SEQ ID NO: 4) active site motif, the circled amino acid residue indicates the active site histidine, and the underlined amino acid residues indicate the yeast putative transmembrane domain.

Fig. 6A,B. Sequence conservation between human and yeast tRNA endonuclease active site subunits Sen2 and Sen34. A. Comparison of Sen2 amino acid sequences in *Saccaromyces*

*cerevisiae* (ScSen2), *Schizosaccharomyces pombe* (SpSen2) and *H. sapiens* (HsSen2). B. Comparison of Sen34 amino acid sequences in *S. cerevisiae* (ScSen34), *S. pombe* (SpSen34) and *H. sapiens* (HsSen34).

Fig. 7A,B. Sequence conservation between human and yeast tRNA endonuclease subunits Sen15 and Sen54. A. Comparison of Sen54 amino acid sequences in *S. cerevisiae* (ScSen54), *S. pombe* (SpSen54) and *H. sapiens* (HsSen54). B. Comparison of Sen15 amino acid sequences in *S. cerevisiae* (ScSen15), *S. pombe* (SpSen15) and *H. sapiens* (HsSen15).

Fig. 8. Protein sequence alignment of Clp1 from different species. hClp1 is evolutionarily conserved and has an ATP/GTP-binding motif. The alignment of *H.sapiens* (tr: Q92989), *D.melanogaster* (tr: Q9V6Q1), *C.elegans* (sp: P52874), *A.thaliana* 1 (gb: AB010077), *A.thaliana* 2 (tr: QSR06), *S.pombe* (tr: Q10299) and *S.cerevisiae* (tr: Q08685) Clp1p sequences was generated with clustalx. The black and gray boxes indicate identical and similar residues, respectively. The conserved Walker A motif with the consensus sequence -A/G-X-X-X-X-G-K-S/T- and the B motif are indicated.

Fig. 9. Identification of components of the tRNA splicing endonuclease complex. His-Flag-Sen2 or His-Flag-Sen34 or His-Flag-Sen15 or His-Flag-Clp1 or His-Flag-Sen54 or His-Flag-Sen2deltaEx8 proteins were purified as described in Example 5.1.2. Proteins co-purified with His-Flag-Sen2, His-Flag-34, His-Flag-Sen15, His-Flag-Clp1, His-Flag-Sen54, His-Flag-Sen2deltaEx8 were analyzed by SDS-PAGE followed by a silver staining. Sen2, Sen34, Sen15, Sen54 and Clp1 are identified as components of the tRNA splicing complex. Extracts from untransfected 293 cells were used as a negative control.

Fig. 10A,B Purification of cell extract fractions containing tRNA splicing endonuclease activity. His-Flag-Sen2, His-Flag-Sen34 and His-Flag-Sen15 proteins were purified as described in Example 5.1.2. Extracts from untransfected 293 cells were used as a negative control. Yeast endonuclease was used as a positive control for endonuclease activity. A. Fractions co-purifying with His-Flag-Sen2 or His-Flag-Sen34 show endonuclease activity, cleaving labeled tRNA at intron/exon borders. B. Fractions co-purifying with His-Flag-Sen15 show endonuclease activity, cleaving labeled tRNA at intron/exon borders. C. Proteins co-purified with Flag-His-HsClp1 have pre-tRNA endonuclease activity.

Fig. 11. Human tRNA Splicing endonuclease active site subunits are localized in the nucleus. Myc-Sen2 (top panel) and GFP-Sen34 (bottom panel) vectors were transiently transfected into HeLa cells and visualized by immunofluorescence

Fig 12. Endonuclease active site subunit Sen2p is alternatively spliced into two distinct forms. Sen2p WT contains all 13 Sen2p exons, while the splice variant Sen2deltaEx8 (also designated as Sen2ΔEx8) contains all exons except Exon 8. An alignment of the active site of the archaeal endonuclease to the human Sen2delta Exon8 subunit suggests that the amino acid sequence of Exon8 corresponds exactly to a conserved Alpha helix of the archaeal endonuclease. The alpha helix serves to orient the N-terminal and C-terminal domains of the active site subunit, forming the basic groove to which Loop L10 from the heterologous Sen15 subunit is proposed to interact.

Fig. 13 A,B. Alternatively spliced endonuclease subunit Sen2ΔEx8 is expressed in many human tissues. A. PCR analysis of the expression of Wild-type Sen2 and splice variant Sen2ΔEx8 in HeLa cells as well as leukemic, liver, kidney, bone marrow, lymphocyte, brain, stomach, and adipocyte tissues as described in Example 5.2.3. B. Northern blot analysis of 70 tissue types probed with an oligonucleotide specific to Sen2ΔEx8 reveals Sen2ΔEx8 expression in an array of tissues.

Fig. 14. Sen2ΔEx8 has decreased ability to bind Sen15 and Sen34. His-Flag-Sen2ΔEx8 or His-Flag-Sen34 or His-Flag-Sen2 proteins were purified as described in Example 5.1.2. Extract prepared from 293 cells was used as a negative control. Proteins co-purified with His-Flag-Sen2ΔEx8 or His-Flag-Sen34 or His-Flag-Sen2 were analyzed by SDS-PAGE followed by a silver staining.

Fig. 15. Endonuclease containing Sen2ΔEx8 is deficient in pre-tRNA cleavage activity. His-Flag-Sen2, His-Flag-Sen34 and His-Flag-Sen2ΔEx8 proteins were purified as described in Example 5.1.2. Extracts from untransfected 293 cells were used as a negative control. Yeast endonuclease was used as a positive control for endonuclease activity. Fractions co-purifying with His-Flag-Sen2 or His-Flag-Sen34 show endonuclease activity, cleaving labeled tRNA at intron/exon borders, whereas fractions co-purifying with His-Flag-Sen2ΔEx8 show deficient endonuclease activity.



Fig. 16. A model of assembly of two distinct complexes human endonuclease complexes. The human holoenzyme appears to consist of five subunits and due to the presence of conserved interaction elements the enzyme can heterotetramerize in a manner analogous to the yeast tRNA splicing endonuclease. Sen2ΔEx8 can dimerize with Sen54 protein, but is unable to form a stable interaction with the Sen34, Sen15. This purified enzyme is able to cleave pre-tRNA in vitro, but in an aberrant fashion. Thus it suggests that in vivo this enzyme may function to process other types of RNA substrates such as pre-mRNA.

Fig. 17. (A) The human endonuclease complexes are associated with pre-mRNA 3' end processing factors. Proteins co-purified with His-Flag-Sen2, His-Flag-Sen2ΔEx8, His-Flag-Sen34, His-Flag-Clp1, His-Flag-Sen15 were analyzed by SDS-PAGE followed by a western blotting with antibodies against the components of 3' end pre-mRNA processing complex, such as CPSF30, Symplekin, CstF64. Y12 antibody that recognizes pre-mRNA splicing SmB/B' proteins was used as a negative control. His-Flag-Sen2ΔEx8 is strongly associated with CPSF30, Symplekin, CstF64 suggesting that Flag-Sen2ΔEx8 is largely involved in pre-mRNA processing. (B) Proteins co-purified with His-Flag-HsSen2, His-Flag-HsSen2ΔEx8, His-Flag-HsSen34, His-Flag-HsSen15 and His-Flag-HsClp1 were analyzed by SDS-PAGE followed by Western blotting with antibodies against Symplekin, CstF64. Y12 antibody that recognizes SmB/B' proteins was used as a negative control. Note that the antibody directed to Cstf-64 recognizes two isoforms of this protein present in 293 cell line (Wallace et al., 1999, PNAS 96:6763-6768).

Fig. 18. Human endonucleases process different types of RNAs. The Sen2 protein together with Sen54, Sen34, Sen15, and Clp1 forms a complex that removes introns from pre-tRNA. Since the Clp1 protein also can be a part of another complex that is involved in maturation of pre-mRNA, we propose that all the subunits of the tRNA splicing endonuclease form a complex with the factors responsible for the 3' end processing of pre-mRNA. Sen2ΔEx8 is unable to form a complex with Sen34 and Sen15 and deficient in pre-tRNA cleavage but it is able to interact with Clp1. As a result of this interaction, Sen2ΔEx8 is involved in the 3' end processing of pre-mRNA.

Fig. 19. depicts an exemplary substrate for 3' end pre-mRNA endonuclease. The pre-mRNA molecule is shown as a line. The positions of the 3' end pre-mRNA endonuclease cleavage site and the internal ribosome entry site are indicated. The open reading frames of two reporter genes, firefly (FLuc) or renilla (RLuc) luciferase are shown as boxes.

Fig. 20. shows the nucleic acid sequence and the amino acid sequence of human Sen2.

Fig. 21. shows the nucleic acid sequence and the amino acid sequence of human Sen2ΔEx8.

Fig. 22. shows the nucleic acid sequence and the amino acid sequence of human Sen15.

5 Fig. 23. shows the nucleic acid sequence and the amino acid sequence of human Sen34.

Fig. 24. shows the nucleic acid sequence and the amino acid sequence of human Sen54.

Fig. 25. shows the nucleic acid sequence and the amino acid sequence of human Clp1.

Fig. 26. Localization of the human tRNA splicing endonuclease subunits. HeLa cells were transiently transfected with a vector encoding GFP-HsSen34 (left panel), Myc-HsSen2  
10 (middle panel) or Myc-HsSen2deltaEx8 (right panel) and analyzed by indirect immunofluorescence microscopy using antibody against myc-epitope.

Fig. 27. Identification of components of the human tRNA splicing endonuclease complex. Proteins co-purified with His-Flag-HsSen2 and His-Flag-HsSen34 (A) or with His-Flag-Sen2deltaEx8 and His-Flag-Sen2 (B) were analyzed by SDS-PAGE followed by silver  
15 staining. Major bands in panel A, lane 3 and panel B, lane 2, correspond to His-Flag-Sen2 and His-Flag-Sen2deltaEx8, respectively. These bands overlap with endogenous HsSen54. Several bands, marked with asterisks, were detected in the control untransfected 293 purification and thus represent nonspecific contaminants of the purification protocol (Hu et al., 2003). Bands 1 and 2 were identified by protein sequence as HsSen15 and HsClp1, respectively. (C) Cell  
20 extract fraction co-purified with His-Flag-HsSen15 was examined for endonuclease activity with labeled pre-tRNA<sup>phe</sup>. Cleavage products were analyzed by denaturing polyacrylamide gel. 293 cell extract was used as a negative control. (D) Proteins co-purified with His-Flag-HsSen54 were analyzed by SDS-PAGE followed by silver staining as described above. We note some additional bands present in HsSen54 purification that are currently under investigation.

25 Fig. 28. HsClp1 and HsSen15 are genuine components of the human tRNA splicing endonuclease complex. (A) Proteins that are co-purified with His-Flag-HsSen15 and His-Flag-HsClp1 were analyzed by SDS-PAGE followed by silver staining. Proteins co-purifying with His-Flag-HsSen2 (on the left) are shown for a comparison with His-Flag-HsSen15 and His-Flag-HsClp1. (B) Cell extract fractions co-purified with His-Flag-HsSen15 were examined for

endonuclease activity with labeled pre-tRNA<sup>Phe</sup>. Cleavage products were analyzed by denaturing polyacrylamide gel. 293 cell extract was used as a negative control.

Fig. 29. The human endonuclease is associated with factors essential for pre-mRNA 3'-end processing. Proteins co-purified with His-Flag-HsSen2, His-Flag-HsSen2deltaEx8, His-Flag-HsSen34, His-Flag-HsSen15 and His-Flag-HsClp1 were analyzed by SDS-PAGE followed by Western blotting with antibodies against Symplekin, CstF64. Y12 antibody that recognizes SmB/B' proteins was used a negative control. We note that our antibody to Cstf-64 recognizes two isoforms of this protein present in 293 cell line (Wallace et al., 1999).

Fig. 30. The human endonuclease is involved in pre-mRNA 3'-end processing. (A) Several 293 cell lines, stably expressing siRNA-A, specific for SEN2 exon 8, or siRNA-B, specific for SEN2 exon 9, were transfected with either His-Flag-HsSen2 (lanes 1-3) or His-Flag-HsSen2deltaEx8. Total cell extracts were prepared from these cells and analyzed by Western blot analysis with anti-FLAG (top) or anti-actin (bottom) antibodies. (B) Quantitative RT-PCR analysis of 293 cells stably expressing siRNA-A or siRNA-B, shown in panel A. White bar corresponds to control siRNA, black bar corresponds to siRNA-A1 and grey bar corresponds to siRNA-B2. (C) (Top) Ribonuclease protection assay of EF1A and GAPDH 3'-extended mRNA. Ten micrograms of yeast total RNA (lane 6), mRNA from 293 cells (lane 5) or 293 stably expressing, siRNA-B1 (lane 2), siRNA-A1 (lane 3) or siRNA-A2 (lane 4) were hybridized to a riboprobe corresponding to the antisense downstream of either the EF1A or GAPDH 3'-end cleavage and polyadenylation site and digested with ribonuclease. Lane 1 represents a 1:250 or 1:100 dilution of the input probe for EF1A or GAPDH, respectively. (Bottom) Measurement of the abundance of 3'-end extended EF1A (grey bars) and GAPDH (black bars) pre-mRNA quantitated by phosphorimager. Data is plotted as fold difference relative to 293 total RNA protected product (lane 5); (D) shows a schematic representation of the primers used with the siRNA experiment.

#### 4. DETAILED DESCRIPTION OF THE INVENTION

The invention provides complexes involved in the processing of RNA. In particular the invention provides complexes with endonuclease activity that are involved in pre-tRNA splicing and/or 3' end pre-mRNA cleavage. More specifically, the invention provides a purified complex

- with RNA-nucleolytic activity comprising two or more or any combination of the following (i) human Sen2 or a functionally active derivative or a functionally active fragment thereof; (ii) human Sen 15 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen34 or a functionally active derivative or a functionally active fragment thereof; and
- 5 (iv) human Sen54 or a functionally active derivative or a functionally active fragment thereof.

The invention provides a purified protein complex with endonuclease activity comprising: (i) human Sen2 or a functionally active derivative or a functionally active fragment thereof; (ii) human Sen 15 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen34 or a functionally active derivative or a functionally active fragment

10 thereof; and (iv) human Sen54 or a functionally active derivative or a functionally active fragment thereof. In a specific embodiment, the protein complex has tRNA splicing endonuclease activity. In another embodiment, the protein complex has 3' end pre-mRNA endonuclease activity. In yet another embodiment, the protein complex has tRNA splicing endonuclease activity and 3' end pre-mRNA endonuclease activity.

15 In certain embodiments, a complex of the invention may further comprise: (i) human CPSF160 or a functionally active derivative or a functionally active fragment thereof; (ii) human CPSF30 or a functionally active derivative or a functionally active fragment thereof; (iii) human CstF64 or a functionally active derivative or a functionally active fragment thereof; and/or (iv) human symplekin or a functionally active derivative or a functionally active fragment.

20 The invention also provides a purified protein complex with endonuclease activity comprising: (i) human Sen2 or a functionally active derivative or a functionally active fragment thereof; (ii) human Sen 15 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen34 or a functionally active derivative or a functionally active fragment thereof; (iv) human Sen54 or a functionally active derivative or a functionally active

25 fragment thereof; and (v) human Clp1 or a functionally active derivative or a functionally active fragment thereof. In a specific embodiment, the protein complex has tRNA splicing endonuclease activity. In another embodiment, the protein complex has 3' end pre-mRNA endonuclease activity. In yet another embodiment, the protein complex has tRNA splicing endonuclease activity and 3' end pre-mRNA endonuclease activity.

30 In certain embodiments, a complex of the invention may further comprise: (i) human CPSF160 or a functionally active derivative or a functionally active fragment thereof; (ii) human CPSF30 or a functionally active derivative or a functionally active fragment thereof; (iii) human CstF64 or a functionally active derivative or a functionally active fragment thereof; and/or (iv)

human symplekin or a functionally active derivative or a functionally active fragment.

The accession numbers of the amino acid sequences of components of the complexes of the invention and nucleotide sequences encoding such components are set forth in Table 1 below.

5       The invention provides a purified protein complex with endonuclease activity comprising: (i) human Sen2 or a functionally active derivative or a functionally active fragment thereof; (ii) human Sen 15 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen34 or a functionally active derivative or a functionally active fragment thereof; (iv) human Sen54 or a functionally active derivative or a functionally active fragment thereof; (v) human Clp1 or a functionally active derivative or a functionally active fragment thereof; (vi) human CPSF or a functionally active derivative or a functionally active fragment thereof; (vii) human CFI<sub>m</sub> or a functionally active derivative or a functionally active fragment thereof; (viii) human CFII<sub>m</sub> or a functionally active derivative or a functionally active fragment thereof; and (ix) human CstF or a functionally active derivative or a functionally active fragment thereof. In a specific embodiment, the protein complex has tRNA splicing endonuclease activity. In another embodiment, the protein complex has 3' end pre-mRNA endonuclease activity. In yet another embodiment, the protein complex has tRNA splicing endonuclease activity and 3' end pre-mRNA endonuclease activity.

20       In certain embodiments, a complex of the invention may further comprise: (i) human CPSF160 or a functionally active derivative or a functionally active fragment thereof; (ii) human CPSF30 or a functionally active derivative or a functionally active fragment thereof; (iii) human CstF64 or a functionally active derivative or a functionally active fragment thereof; and/or (iv) human symplekin or a functionally active derivative or a functionally active fragment.

25       The invention provides a splice variant of human Sen2, namely human Sen2deltaEx8. In particular, the invention provides nucleic acid sequences encoding human Sen2deltaEx8 or a functionally active fragment or a functionally active derivative thereof, and amino acid sequences coding human Sen2deltaEx8 or a functionally active fragment or a functionally active derivative thereof. In a specific embodiment, the invention provides a nucleic acid sequence that hybridizes under stringent conditions to a nucleic acid sequence encoding Sen2ΔEx8 over the entire length of the nucleic acid sequence encoding Sen2ΔEx8. In another embodiment, the invention provides nucleic acid sequences that encode a protein having an amino acid sequence that is at least 90%, preferably at least 95%, at least 98%, at least 99%, at least 99.5%, at least 99.8% or at least 99.9% identical to the amino acid sequence of SEQ ID NO:12, wherein the

protein is different from Sen2 (Accession No.: NP\_079541). In another embodiment, the invention provides a nucleic acid sequence comprising the nucleic acid sequence of SEQ ID NO:11. The invention further provides vectors comprising a nucleic acid sequence encoding human Sen2ΔEx8 and host cells comprising the vector. The invention further provides host  
5 cells comprising a nucleic acid encoding human Sen2ΔEx8.

The invention provides a purified protein, wherein the protein consists essentially of the amino acid sequence of SEQ ID NO:12 or an amino acid sequence that is at least 90%, preferably at least 95%, at least 98%, at least 99%, at least 99.5%, at least 99.8% or at least 99.9% identical to the amino acid sequence of SEQ ID NO:12. The invention further provides  
10 antibodies or fragments thereof that immunospecifically bind to human Sen2ΔEx8 but do not bind to Sen2. In particular the invention provides an antibody or fragment thereof that immunospecifically binds to the unique region of Sen2ΔEx8 that is created by the deletion of Exon 8 from the Sen2 protein.

The invention also provides purified protein complexes comprising human  
15 Sen2deltaEx8. The Sen2deltaEx8 complexes have RNA-nucleolytic activity. In a specific embodiment, the Sen2deltaEx8 complexes have pre-tRNA cleavage activity and/or 3' end pre-mRNA endonuclease activity. The invention provides a purified human Sen2deltaEx8 complex comprising: (i) human Sen2deltaEx8 or a functionally active derivative thereof; and (ii) human Sen54 or a functionally active derivative or a functionally active fragment thereof. The  
20 invention also provides a human Sen2deltaEx8 complex with comprising: (i) human Sen2deltaEx8 or a functionally active derivative thereof; (ii) human Sen54 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen15 or a functionally active derivative or a functionally active fragment thereof; and (iv) human Sen34 or a functionally active derivative or a functionally active fragment thereof. In certain embodiments,  
25 the Sen2deltaEx8 complex has RNA-nucleolytic activity. In a specific embodiment the Sen2deltaEx8 complex has tRNA endonuclease and/or 3' end mRNA processing activity. In certain embodiments, the fidelity and accuracy of the tRNA cleavage activity of a Sen2deltaEx8 comprising complex is reduced compared to the the tRNA cleavage activity of full length Sen2 comprising complexes. In certain embodiments, the complex may further comprise: (i) human  
30 CPSF160 or a functionally active derivative or a functionally active fragment thereof; (ii) human CPSF30 or a functionally active derivative or a functionally active fragment thereof; (iii) human CstF64 or a functionally active derivative or a functionally active fragment thereof; and/or (iv) human symplekin or a functionally active derivative or a functionally active fragment. These

human Sen2deltaEx8 complexes cleave tRNA at multiple sites and are useful in mapping RNA structure and 3' end endonuclease processing. In certain embodiments, the fidelity and accuracy of the tRNA cleavage activity of a Sen2deltaEx8 comprising complex is reduced compared to the the tRNA cleavage activity of full length Sen2 comprising complexes.

5       The invention provides a purified human Sen2deltaEx8 complex comprising: (i) human Sen2deltaEx8 or a functionally active derivative thereof; (ii) human Sen54 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen15 or a functionally active derivative or a functionally active fragment thereof; (iv) human Sen34 or a functionally active derivative or a functionally active fragment thereof; and (v) human Clp1 or a functionally  
10   active derivative or a functionally active fragment thereof. In certain embodiments, the Sen2deltaEx8 complex has RNA-nucleolytic activity. In a specific embodiment the Sen2deltaEx8 complex has tRNA endonuclease and/or 3' end mRNA processing activity. In certain embodiments, the fidelity and accuracy of the tRNA cleavage activity of a Sen2deltaEx8 comprising complex is reduced compared to the the tRNA cleavage activity of full length Sen2  
15   comprising complexes. In certain embodiments, the complex may further comprise: (i) human CPSF160 or a functionally active derivative or a functionally active fragment thereof; (ii) human CPSF30 or a functionally active derivative or a functionally active fragment thereof; (iii) human CstF64 or a functionally active derivative or a functionally active fragment thereof; and/or (iv) human symplekin or a functionally active derivative or a functionally active fragment. The  
20   invention also provides a purified human Sen2deltaEx8 complex comprising: (i) human Sen2deltaEx8 or a functionally active derivative thereof; (ii) human Sen54 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen15 or a functionally active derivative or a functionally active fragment thereof; (iv) human Sen34 or a functionally active derivative or a functionally active fragment thereof; (v) human Clp1 or a functionally  
25   active derivative or a functionally active fragment thereof; (vi) human CSPF or a functionally active derivative or a functionally active fragment thereof; (vii) human CFI<sub>m</sub> or a functionally active derivative or a functionally active fragment thereof; (viii) human CFII<sub>m</sub> or a functionally active derivative or a functionally active fragment thereof; and (ix) human CstF or a functionally active derivative or a functionally active fragment thereof. The invention also provides a  
30   purified human Sen2deltaEx8 complex comprising: (i) human Sen2deltaEx8 or a functionally active derivative thereof; (ii) human Sen54 or a functionally active derivative or a functionally active fragment thereof; and (iii) human Clp1 or a functionally active derivative or a functionally active fragment thereof, and optionally (i) human CPSF or a functionally active

derivative or a functionally active fragment thereof; (ii) human CFI<sub>m</sub> or a functionally active derivative or a functionally active fragment thereof; (iii) human CFIL<sub>m</sub> or a functionally active derivative or a functionally active fragment thereof; and (iv) human CstF or a functionally active derivative or a functionally active fragment thereof. In certain embodiments, the complexes of  
5 the invention have RNA nucleolytic activity. In certain, more specific embodiments, the complexes have tRNA cleavage activity and/or 3' end pre-mRNA processing activity.

The invention also provides protein complexes with pre-ribosomal RNA cleavage activity. In particular, the invention provides a protein complex with pre-ribosomal RNA cleavage activity comprising: (i) human Sen15 or a functionally active derivative or a  
10 functionally active fragment thereof; and (ii) human Sen34 or a functionally active derivative or a functionally active fragment thereof. This protein complex may be used in the biogenesis of different ribosomal RNAs. For example, the production of 28S, 18S, 5.5S and 5S ribosomal RNA may be altered by modulating this protein complex.

The invention provides methods for purifying a complex of the invention. In particular,  
15 the invention provides a method for purifying a complex of the invention, the method comprising: preparing a cell extract or a nuclear extract from a cell, wherein the cell expresses all of the protein components of the complex and wherein at least one of the protein components is fused to a peptide tag; and purifying the complex by virtue of the peptide tag.

The invention provides antibodies or fragments thereof that immunospecifically bind to a  
20 complex of the invention. In a specific embodiment, the invention provides an antibody or a fragment thereof that immunospecifically binds to a complex of the invention with higher affinity than to each individual component of the complex in an immunoassay well-known to one of skill in the art or described herein. In another embodiment, the invention provides an antibody or a fragment thereof that immunospecifically binds to a complex of the invention, but  
25 does not bind to each individual component of the complex in an immunoassay well-known to one of skill in the art or described herein. The invention also provides a method for generating an antibody or a fragment thereof that immunospecifically binds to a complex of the invention comprising immunizing a subject with the complex of the invention.

The invention also provides antibodies or fragments thereof that immunospecifically  
30 bind to one of the following components of a complex of the invention: (i) human Sen2 or a functionally active derivative or a functionally active fragment thereof; (ii) human Sen2deltaEx8 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen15 or a functionally active derivative or a functionally active fragment thereof; (iv) human Sen34 or a



functionally active derivative or a functionally active fragment thereof; and (v) human Sen54 or a functionally active derivative or a functionally active fragment thereof. Preferably, the antibodies or fragments thereof are not known. The invention also provides a method for generating an antibody or a fragment thereof that immunospecifically binds to a component of a complex of the invention comprising immunizing a subject with the component.

In a specific embodiment, the invention provides an antibody or a fragment thereof that immunospecifically binds to human Sen2deltaEx8 with higher affinity than human Sen2 in an immunoassay well-known to one of skill in the art or described herein. In another embodiment, the invention provides an antibody or a fragment thereof that immunospecifically binds to human Sen2deltaEx8, but does not bind to human Sen2 in an immunoassay well-known to one of skill in the art or described herein.

The invention provides methods of identifying compounds that modulate the expression (at the RNA and/or protein level) of one or more of the following components of a complex of the invention: (i) human Sen2 or a functionally active derivative or a functionally active fragment thereof; (ii) human Sen2deltaEx8 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen15 or a functionally active derivative or a functionally active fragment thereof; (iv) human Sen34 or a functionally active derivative or a functionally active fragment thereof; and/or (v) human Sen54 or a functionally active derivative or a functionally active fragment thereof. Techniques for measuring expression of proteins are well-known to one of skill in the art and include, *e.g.*, immunoassays for protein expression levels, and RT-PCR or Northern blots for RNA expression levels.

The invention provides screening assays to identify compounds that modulate the formation of a complex of the invention. In particular, the invention provides methods for identifying compounds that stabilize or promote the formation of a complex of the invention. The invention also provides methods for identifying compounds that destabilize or promote the dissociation of a complex of the invention. Such methods can be cell-based or they can be conducted in a cell-free system.

The present invention also provides methods for identifying compounds that modulate the RNA-nucleolytic activity of a complex of the invention. In particular, the invention provides methods for identifying a compound that modulates the pre-tRNA processing activity and/or 3' end pre-mRNA processing activity of a complex of the invention using assays well-known to one of skill in the art or described herein. For example, reporter gene-based assays, FRET assays and FISH assays may be used to in accordance with the methods of the invention to

identify compounds that modulate the RNA-nucleolytic activity of a complex of the invention.

The present invention further provides methods for identifying compounds that modulate the pre-tRNA cleavage activity and/or pre-ribosomal RNA cleavage activity of a complex of the invention. Techniques well-known to one of skill in the art or described herein may be used to measure the ability of a compound to modulate the pre-tRNA cleavage activity and/or pre-ribosomal RNA cleavage activity of a complex of the invention. For example, the ability of a compound to modulate the pre-tRNA cleavage activity of a complex of the invention may be determined by comparing the level of tRNA fragments produced from a tRNA in the presence of the compound relative to the level of tRNA fragments produced from the same tRNA in the absence of the compound or the presence of an appropriate control (*e.g.*, a negative control such as PBS), wherein a change in the levels indicates that the compound modulates the pre-tRNA cleavage activity of the complex. The ability of a compound to modulate the pre-ribosomal RNA cleavage activity of a complex of the invention may be determined by, *e.g.*, comparing the level of specific ribosomal RNAs (*e.g.*, 28S, 18S, 5.8S and/or 5S) produced from a pre-ribosomal RNA in the presence of the compound relative to the level of the ribosomal RNA produced from the same pre-ribosomal RNA in the absence of the compound or the presence of an appropriate control (*e.g.*, a negative control such as PBS), wherein a change in the levels indicates that the compound modulates the pre-ribosomal RNA cleavage activity of the complex.

A compound identified in assays described herein that modulates the expression of a component of a complex of the invention, the formation of a complex of the invention, the RNA-nucleolytic activity of a complex of the invention (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention) may be tested in *in vitro* assays (*e.g.*, cell-based assays or cell-free assays) or *in vivo* assays well-known to one of skill in the art or described herein for the effect of the compound a disorder described herein (*e.g.*, a proliferative disorder or a disorder characterized by, associated with or caused by abnormal RNA-nucleolytic activity) or on cells from a patient with a particular disorder.

In a specific embodiment, a compound identified in assays described herein that inhibits or reduces the expression of a component of a complex of the invention, the formation of a complex of the invention, the RNA-nucleolytic activity of a complex of the invention (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage

activity of a complex of the invention) may be tested in *in vitro* assays (*e.g.*, cell-based assays or cell-free assays) or *in vivo* assays well-known to one of skill in the art or described herein for the antiproliferative effect of the compound on hyperproliferative cells versus normal cells. In another embodiment, a compound identified in assays described herein that inhibits or reduces the expression of a component of a complex of the invention, the formation of a complex of the invention, the RNA-nucleolytic activity of a complex of the invention (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention) may be tested in an animal model for cancer to determine the efficacy of the compound in the prevention, treatment or amelioration of cancer or a symptom thereof. In yet another embodiment, a compound identified in assays described herein that enhances the expression of a component of a complex of the invention, the formation of a complex of the invention, the RNA-nucleolytic activity of a complex of the invention (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention) may be tested for its effect on wound healing.

The structure of the compounds identified in the assays described herein that modulate the expression of a component of a complex of the invention, the formation of a complex of the invention, the RNA-nucleolytic activity of a complex of the invention (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention) can be determined utilizing assays well-known to one of skill in the art or described herein. The methods used will depend, in part, on the nature of the library screened. For example, assays or microarrays of compounds, each having an address or identifier, may be deconvoluted, *e.g.*, by cross-referencing the positive sample to an original compound list that was applied to the individual test assays. Alternatively, the structure of the compounds identified herein may be determined using mass spectrometry, nuclear magnetic resonance ("NMR"), circular dichroism, X ray crystallography, or vibrational spectroscopy.

The invention encompasses the use of the compounds that inhibit or reduce the expression of a component of a complex of the invention, the formation of a complex of the invention, the RNA-nucleolytic activity of a complex of the invention, (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity

of a complex of the invention) which were identified in accordance with the methods described herein for the prevention, treatment, management or amelioration of a proliferative disorder or a symptom thereof, or a disorder characterized by, associated with or caused by increased RNA-nucleolytic activity (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention) or a symptom thereof. The invention encompasses the use of the compounds that stimulate or enhance the expression of a component of a complex of the invention, the formation of a complex of the invention, the RNA-nucleolytic activity of a complex of the invention (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention) which were identified in accordance with the methods described herein for the prevention, treatment, management or amelioration of a disorder characterized by, associated with or caused by decreased RNA-nucleolytic activity (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention). The invention also encompasses the use of the compounds that stimulate or enhance the expression of a component of a complex of the invention, the formation of a complex of the invention, the RNA-nucleolytic activity of a complex of the invention, (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention) which were identified in accordance with the methods described herein for augmenting wound healing in a subject.

The invention provides compositions comprising a carrier and one the following or a combination of two or more of the following: (i) a component of the a complex of the invention; (ii) a complex of the invention, (iii) an antibody or a fragment thereof that immunospecifically binds to a component of a complex of the invention, or a complex of the invention, (iv) a compound that modulates the expression of a component of a complex of the invention, (v) a compound that modulates the formation of a complex of the invention, (vi) a compound that modulates the endonuclease activity (*e.g.*, tRNA splicing endonuclease activity and/or 3' end pre-mRNA endonuclease activity) of a complex of the invention, (vii) a compound that modulates the pre-tRNA cleavage activity of a complex of the invention, and/or (viii) a compound that modulates pre-ribosomal RNA cleavage activity of a complex of the invention.

The compositions may further comprise one or more other prophylactic or therapeutic agents. In a preferred embodiment, the compositions are pharmaceutical compositions. In accordance with this embodiment, the pharmaceutical compositions are preferably sterile and in suitable form for the intended method of administration or use. The invention encompasses the use of  
5 the compositions of the invention in the prevention, treatment, management or amelioration of a disorder described herein or a symptom thereof.

The invention also provides methods for detecting, diagnosing or monitoring a proliferative disorder or a disorder associated with, characterized by or caused by abnormal pre-tRNA processing and/or 3' end pre-mRNA processing utilizing an antibody that  
10 immunospecifically binds to a complex of the invention or a component thereof, or a compound identified in accordance with the methods of the invention that specifically binds to a complex of the invention or a component thereof. The invention also provides methods for detecting, diagnosing or monitoring a proliferative disorder or a disorder associated with, characterized by or caused by abnormal pre-tRNA processing and/or 3' end pre-mRNA processing by comparing  
15 the RNA-nucleolytic activity of a complex purified from cells or a tissue sample from a subject with such a disorder or suspected of having such disorder to the RNA-nucleolytic activity of a control, *e.g.*, a complex purified from normal, non-cancerous cells or a tissue sample, using an assay well-known to one of skill in the art or described herein. The invention further provides methods for detecting, diagnosing or monitoring a proliferative disorder or a disorder associated  
20 with, characterized by or caused by abnormal pre-tRNA processing and/or 3' end pre-mRNA processing by comparing the structure of a complex of the invention purified from cells or a tissue sample from a subject (*e.g.*, a subject with such a disorder or suspected of having such a disorder) to the structure of a control, *e.g.*, a complex of the invention purified from normal, non-cancerous cells or a tissue sample, using an assay well-known to one of skill in the art (*e.g.*,  
25 circular circular dichroism and nuclear magnetic resonance).

#### 4.1 Sen2ΔEx8

The invention provides nucleic acids encoding a splice variant of Sen2, termed Sen2ΔEx8 or Sen2deltaEx8. The Sen2ΔEx8 is a splice variant of human Sen2 lacking exon 8 of  
30 the genomic DNA sequence for human Sen2. Figure 2 depicts an amino acid sequence alignment of the amino acid sequences of the two human Sen 2 subunits (*i.e.*, Hs Sen2 and Sen2ΔEx8) and the amino acid sequence of the yeast subunit Sc Sen 2p. The sequence

alignment reveals a high degree of similarity in the YRGGY motif, the active site for the 5' splice site of yeast (Sc Sen 2p) and archael (not shown) tRNA splicing endonuclease. Based upon the sequence alignment, human Sen2ΔEx8 lacks the putative transmembrane domain found in the human Sen 2 endonuclease, which may affect the localization of the Sen2ΔEx8 in a human cell.

The invention provides for nucleic acid sequences encoding human Sen2ΔEx8 or functionally active fragments, or functionally active derivatives thereof. In particular, the invention provides a nucleic acid sequence comprising a contiguous nucleotide sequence identical to the nucleotide sequence of SEQ ID NO:1. The invention also provides nucleic acid sequences that are at least 90%, preferably at least 95%, at least 98%, at least 99%, at least 99.5%, or at least 99.8% identical to the nucleotide sequence of SEQ ID NO:1 or a complement thereof. The invention provides nucleic acid sequences which comprise at least 15, preferably at least 20, at least 25, at least 30, at least 35, at least 40, at least 45, at least 50 or more contiguous nucleotides of the nucleotide sequence of nucleotide of SEQ ID NO:1 or a complement thereof, wherein the nucleotide sequence comprises nucleotide 910 to nucleotide 960 of SEQ ID NO:1 or a complement thereof. The invention also provides nucleic acid sequences comprising a contiguous nucleotide sequence that hybridizes under high stringency conditions to the nucleotide sequence of SEQ ID NO:1 or a complement thereof over the entire length of the nucleic acid sequence of SEQ ID NO:1.

The invention provides nucleic acid sequences comprising a contiguous nucleotide sequence that encodes a polypeptide of the amino acid sequence of SEQ ID NO:12. The invention also provides nucleic acid sequences comprising a contiguous nucleotide sequence that encodes a polypeptide of an amino acid sequence that is at least 90%, preferably at least 95%, at least 98%, at least 99%, at least 99.5%, or at least 99.8% identical to the amino acid sequence of SEQ ID NO:12. The invention also provides nucleic acid sequences comprising a nucleotide sequence that encodes a polypeptide comprising at least 10, preferably at least 15, at least 20, or at least 25, at least 30, at least 35, at least 40, at least 45, at least 50, at least 55 or more contiguous amino acids of amino acid sequence of SEQ ID NO:12, wherein the polypeptide contains residues 311 to 327 of SEQ ID NO:12. The invention also provides nucleic acid sequences that hybridize under highly stringent conditions to a nucleic acid sequence encoding the amino acid sequence of SEQ ID NO:12 over the entire length of the nucleic acid sequence encoding the amino acid sequence of SEQ ID NO:12.

The invention provides host cells containing or comprising a nucleic acid sequence

encoding Sen2ΔEx8, such as, but not limited to, the nucleic acid of SEQ ID NO:11. The invention also provides a vector comprising a nucleic acid sequence comprising a nucleotide sequence encoding Sen2ΔEx8, such as, but not limited to, the nucleic acid of SEQ ID NO:11. The invention also provide host cells containing or comprising a vector comprising a nucleic acid sequence comprising a nucleotide sequence encoding Sen2ΔEx8, such as, but not limited to, the nucleic acid of SEQ ID NO:11. Techniques well-known to one of skill in the art, such as electroporation, calcium phosphate precipitate and liposomes, may be used to transfect a host cell with a nucleic acid sequence encoding Sen2ΔEx8 or a functionally active fragment or derivative thereof. See, *e.g.*, Section 4.5.4.1.4 and 4.5.4.1.5, *infra*, for a description of vectors, transfection techniques and host cells. Techniques well-known to one of skill in the art, such as immunoprecipitation using antibodies immunospecific human Sen2ΔEx8 or a functionally active fragment or derivative thereof, may be used to purify human Sen2ΔEx8 or a functionally active fragment or derivative thereof. See Section 4.3, *infra*, for a description of methods of purify proteinaceous agents such as human Sen2ΔEx8 or a functionally active fragment or derivative thereof.

The invention provides amino acid sequences of human SenΔEx8 or functionally active fragments, or functionally active derivatives thereof. In particular, the invention provides a purified protein comprising the amino acid sequence of SEQ ID NO:12. The invention also provides a purified protein that is at least 90%, preferably at least 95%, at least 98%, at least 99%, at least 99.5%, or at least 99.8% identical to the amino acid sequence of SEQ ID NO:12. The invention also provides a purified protein encoded by a nucleotide sequence that hybridizes over its full-length under highly stringent conditions to the nucleotide sequence of SEQ ID NO:11. The invention also provides a purified polypeptide comprising at least 10, preferably at least 15, at least 20, or at least 25, at least 30, at least 35, at least 40, at least 45, at least 50, at least 55 or more contiguous amino acids of amino acid sequence of SEQ ID NO:12, wherein the polypeptide contains residues 311 to 327 of SEQ ID NO:12. The invention also provides a purified protein comprising a contiguous nucleotide sequence that encodes a polypeptide that is at least 90%, preferably at least 95%, at least 98%, at least 99%, at least 99.5%, or at least 99.8% identical to the amino acid sequence of SEQ ID NO:12.

The invention also provides fusion proteins comprising human Sen2ΔEx8 or a functionally active fragment or a functionally active derivative thereof and a heterologous amino acid sequence (*i.e.*, a different amino acid sequence; an amino acid sequence not naturally found in conjunction with the amino acid sequence of human Sen2ΔEx8).

## 4.2 Complexes of the Invention

### 4.2.1 tRNA Splicing Endonuclease Complex

The invention provides a purified protein complex with tRNA endonuclease activity comprising two or more of the following: (i) human Sen2 or a functionally active derivative or a functionally active fragment thereof; (ii) human Sen 15 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen34 or a functionally active derivative or a functionally active fragment thereof; and (iv) human Sen54 or a functionally active derivative or a functionally active fragment thereof.

In particular, the invention provides a purified protein complex with tRNA splicing endonuclease activity comprising: (i) human Sen2 or a functionally active derivative or a functionally active fragment thereof; (ii) human Sen 15 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen34 or a functionally active derivative or a functionally active fragment thereof; and (iv) human Sen54 or a functionally active derivative or a functionally active fragment thereof. In one embodiment, the invention provides a purified complex with tRNA splicing endonuclease activity comprising: (i) human Sen2 (ACCESSION NO.: NP\_079541), or a protein encoded by a nucleic acid that hybridizes to the human Sen2 encoding nucleic acid (ACCESSION NO.: NM\_025265) or its complement under high stringency conditions; (ii) human Sen15 (ACCESSION NO.: NP\_443197), or a protein encoded by a nucleic acid that hybridizes to the human Sen15 encoding nucleic acid (ACCESSION NO.: NM\_052965) or its complement under high stringency conditions; (iii) human Sen34 (ACCESSION NO.: NP\_076980), or a protein encoded by a nucleic acid that hybridizes to the human Sen34 encoding nucleic acid (ACCESSION NO.: NM\_024075) or its complement under high stringency conditions; and (iv) Sen54 (ACCESSION NO.: XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the human Sen54 encoding nucleic acid (ACCESSION NO.: XM\_208944) or its complement under high stringency conditions.

In a specific embodiment, the protein complex has 3' end pre-mRNA endonuclease activity. In another embodiment, the protein complex has tRNA splicing endonuclease activity and 3' end pre-mRNA endonuclease activity.

The invention also provides a purified protein complex with tRNA endonuclease activity comprising: (i) human Sen2 or a functionally active derivative or a functionally active fragment thereof; (ii) human Sen 15 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen34 or a functionally active derivative or a functionally active fragment thereof; and (iv) human Sen54 or a functionally active derivative or a functionally active fragment thereof.



thereof; (iv) human Sen54 or a functionally active derivative or a functionally active fragment thereof; and (v) human Clp1 or a functionally active derivative or a functionally active fragment thereof.

In certain embodiments, the Sen2deltaEx8 complex has RNA-nucleolytic activity. In a specific embodiment the Sen2deltaEx8 complex has tRNA endonuclease and/or 3' end mRNA processing activity. In certain embodiments, the fidelity and accuracy of the tRNA cleavage activity of a Sen2deltaEx8 comprising complex is reduced compared to the the tRNA cleavage activity of full length Sen2 comprising complexes. In certain embodiments, the complex may further comprise: (i) human CPSF160 or a functionally active derivative or a functionally active fragment thereof; (ii) human CPSF30 or a functionally active derivative or a functionally active fragment thereof; (iii) human CstF64 or a functionally active derivative or a functionally active fragment thereof; and/or (iv) human symplekin or a functionally active derivative or a functionally active fragment.

In one embodiment, the invention provides a purified complex with tRNA splicing endonuclease activity comprising: (i) human Sen2 (ACCESSION NO.: NP\_079541), or a protein encoded by a nucleic acid that hybridizes to the human Sen2 encoding nucleic acid (ACCESSION NO.: NM\_025265) or its complement under high stringency conditions; (ii) human Sen15 (ACCESSION NO.:NP\_443197), or a protein encoded by a nucleic acid that hybridizes to the human Sen15 encoding nucleic acid (ACCESSION NO.:NM\_052965) or its complement under high stringency conditions; (iii) human Sen34 (ACCESSION NO.:NP\_076980), or a protein encoded by a nucleic acid that hybridizes to the human Sen34 encoding nucleic acid (ACCESSION NO.:NM\_024075) or its complement under high stringency conditions; (iv) Sen54 (ACCESSION NO.:XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the human Sen54 encoding nucleic acid (ACCESSION NO.:XM\_208944) or its complement under high stringency conditions; and (v) human Clp1 (ACCESSION NO.:NP\_006822) or a protein encoded by a nucleic acid that hybridizes to the human Clp1 encoding nucleic acid (ACCESSION NO.: NM\_006831) or its complement under high stringency conditions. In certain embodiments, the Sen2deltaEx8 complex has RNA-nucleolytic activity. In a specific embodiment the Sen2deltaEx8 complex has tRNA endonuclease and/or 3' end mRNA processing activity. In certain embodiments, the fidelity and accuracy of the tRNA cleavage activity of a Sen2deltaEx8 comprising complex is reduced compared to the the tRNA cleavage activity of full length Sen2 comprising complexes. In certain embodiments, the complex may further comprise: (i) human CPSF160 or a protein

encoded by a nucleic acid that hybridizes under stringent conditions to a CPSF160 encoding nucleic acid; (ii) human CPSF30 or a protein encoded by a nucleic acid that hybridizes under stringent conditions to a CPSF30 encoding nucleic acid; (iii) human CstF64 or a protein encoded by a nucleic acid that hybridizes under stringent conditions to a CstF64 encoding nucleic acid; and/or (iv) human symplekin or a protein encoded by a nucleic acid that hybridizes under stringent conditions to a symplekin encoding nucleic acid. In a specific embodiment, the protein complex has 3' end pre-mRNA endonuclease activity. In another embodiment, the protein complex has tRNA splicing endonuclease activity and 3' end pre-mRNA endonuclease activity.

The invention provides a purified protein complex with tRNA splicing endonuclease activity comprising: (i) human Sen2 or a functionally active derivative or a functionally active fragment thereof; (ii) human Sen 15 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen34 or a functionally active derivative or a functionally active fragment thereof; (iv) human Sen54 or a functionally active derivative or a functionally active fragment thereof; (v) human Clp1 (ACCESSION NO.:NP\_006822) or a functionally active derivative or a functionally active fragment thereof; (vi) human Cleavage-Polyadenylation Specificity Factor ("CPSF") or a functionally active derivative or a functionally active fragment thereof; (vii) human Cleavage Factor I<sub>m</sub> ("CFI<sub>m</sub>") or a functionally active derivative or a functionally active fragment thereof; (viii) human Cleavage Factor II<sub>m</sub> ("CFII<sub>m</sub>") or a functionally active derivative or a functionally active fragment thereof; and (ix) human Cleavage Stimulation Factor ("CSF") or a functionally active derivative or a functionally active fragment thereof. In a specific embodiment, the protein complex has 3' end pre-mRNA endonuclease activity. In another embodiment, the protein complex has tRNA splicing endonuclease activity and 3' end pre-mRNA endonuclease activity.

CPSF, CstF, CFI<sub>m</sub> and CFII<sub>m</sub> consist of multiple subunits. The accession numbers of the different subunits are set forth in Table 1 below. CPSF, CstF, CFI<sub>m</sub> and CFII<sub>m</sub> can each comprise a different set of subunits. In a specific embodiment, CPSF comprises the 160 kD factor 1 and the 30 kD factor 4. In a more specific embodiment, CPSF comprises the 160 kD factor 1, the 100 kD factor 2, the 73 kD factor 3, and the 30 kD factor 4. In a specific embodiment, CstF comprises the 50 kD subunit 1, the 64 kD subunit 2, and the 77 kD subunit 3. In a more specific embodiment, CstF comprises the 50 kD subunit 1, the 64 kD subunit 2, the 77 kD subunit 3, and symplekin. In a specific embodiment, CFI<sub>m</sub> comprises the 68 kD subunit and the 25 kD subunit. In a more specific embodiment, CFI<sub>m</sub> comprises the 68 kD subunit, the 25 kD subunit, the 59 kD subunit, and the 72 kD subunit. In a specific embodiment, CFII<sub>m</sub>

comprises Clp1. In a more specific embodiment, CFII<sub>m</sub> comprises Clp1 and hPcf11. In another more specific embodiment, CFII<sub>m</sub> comprises ClpI, the CFIm 25 kD subunit and the CFIm 68 kD subunit. In even another more specific embodiment, CFII<sub>m</sub> comprises ClpI, the CFIm 25 kD subunit and the CFIm 68 kD subunit and hpcf11.

5 Detailed information on Symplekin can be obtained from the homepage of Dr. Keller's laboratory at the biocentre of the University of Basel and in Takagaki, Y. and J. Manley, 2000, *Molecular & Cellular Biol* 20:1515-1525.

Wahle and Ruegsegger, 1999, *FEMS Micro Rev.*, 23, 277-295 and Zhao et al., 1999, *Micoboil. Mol. Biol. Rev.*, 63, 405-445 describe factors involved RNA processing, both  
10 references are incorporated herein in their entireties.

In certain embodiments, all subunits of CPSF and CstF, respectively, are present in a complex of the invention.

TABLE 1: GenBank Accession Numbers

15

NAME	NUCLEOTIDE ACC. NO.	PROTEIN ACC. NO.
Sen2	NM_025265	NP_079541
Sen2deltaEx8	SEQ ID NO:11	SEQ ID NO:12
Sen15	NM_052965 AF288394	NP_443197 AAG60614
Sen34	NM_024075; XP_085899	NP_076980
Sen54	XM_208944	XP_208944
Clp1	NM_006831	NP_006822
CFII <sub>m</sub> subunit hPcf11	NM_015885	NP_056969
CFII <sub>m</sub> subunit Clp1	NM_006831	NP_006822
CFI <sub>m</sub> 25 kD subunit	NM_007006 AJ001810	NP_008937 CAA05026
CFI <sub>m</sub> 59 kD subunit	NM_024811.2 AJ275970	NP_079087 CAC81661

CFI <sub>m</sub> 68 kD subunit	NM_007007 X67337	NP_008938 CAA47752
CFI <sub>m</sub> 72 kD subunit	See, <i>e.g.</i> , de Vries <i>et al.</i> , 2000, EMBO J. 19:5895-5904	
CstF50 (50 kD subunit 1)	NM_001324	NP_001315
CstF64 (64 kD subunit 2)	NM_001325 NM_015235	NP_001316 NP_056050
CstF77 (77 kD subunit 3)	NM_001326	NP_001317
CstF subunit Symplekin	NM_004819	NP_004810
CPSF160 (160 kD factor 1)	NM_013291 XM_209402	NP_037423 XP_209402
CPSF100 (100 kD factor 2)	XM_029311.2	XP_029311
CPSF73 (73 kD factor 3)	NM_016207	NP_057291
CPSF30 (30 kD factor 4)	NM_006693 XM_292584	NP_006684 XP_292584
FIP subunit of CPSF		
PFS2 subunit of CPSF		

In one embodiment, the invention provides a purified complex with tRNA splicing endonuclease activity comprising: (i) human Sen2 (ACCESSION NO.: NP\_079541), or a protein encoded by a nucleic acid that hybridizes to the human Sen2 encoding nucleic acid (ACCESSION NO.: NM\_025265) or its complement under high stringency conditions; (ii)

5 human Sen15 (ACCESSION NO.:NP\_443197), or a protein encoded by a nucleic acid that hybridizes to the human Sen15 encoding nucleic acid (ACCESSION NO.:NM\_052965) or its complement under high stringency conditions; (iii) human Sen34 (ACCESSION NO.:NP\_076980), or a protein encoded by a nucleic acid that hybridizes to the human Sen34 encoding nucleic acid (ACCESSION NO.:NM\_024075) or its complement under high

10 stringency conditions; (iv) Sen54 (ACCESSION NO.:XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the human Sen54 encoding nucleic acid (ACCESSION NO.:XM\_208944) or its complement under high stringency conditions; (v) human Clp1 (ACCESSION NO.:NP\_006822) or a protein encoded by a nucleic acid that hybridizes to the human Clp1 encoding nucleic acid (ACCESSION NO.: NM\_006831) or its complement under

high stringency conditions; (vi) human Cleavage-Polyadenylation Specificity Factor ("CPSF") or a protein encoded by a nucleic acid that hybridizes to the human CPSF or its complement under high stringency conditions; (vii) human Cleavage Factor I<sub>m</sub> ("CF I<sub>m</sub>") or a protein encoded by a nucleic acid that hybridizes to the human CFI<sub>m</sub> encoding nucleic acid or its complement under high stringency conditions; (viii) human Cleavage Factor II<sub>m</sub> ("CF II<sub>m</sub>") or a protein encoded by a nucleic acid that hybridizes to the human CFII<sub>m</sub> encoding nucleic acid or its complement under high stringency conditions; and (ix) human Cleavage Stimulation Factor ("CSF") or a protein encoded by a nucleic acid that hybridizes to the human CstF encoding nucleic acid or its complement under high stringency conditions. In accordance with this embodiment, the complex may also have 3' end pre-mRNA endonuclease activity.

In certain, more specific embodiments, a complex of the invention is purified.

In certain embodiments, the invention provides complexes that comprise homologs or analogs of the human proteins of the complexes of the invention. Homologs or analogs of the components of a complex of the invention are at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 98%, at least 99% or at least 99.5% identical to a human protein of a complex of the invention. Derivatives can be, e.g., fusion proteins, mutant forms of the protein, or forms of the protein with chemical moieties linked to the protein. A fragment of a component of a complex of the invention is a portion of the protein component that maintains the ability of the component to be physically integrated into the complex.

In certain embodiments, the protein components of a complex of the invention are derived from the same species. In more specific embodiments, the protein components are all derived from human. In another specific embodiment, the protein components are all derived from a mammal.

In certain other embodiments, the protein components of a complex of the invention are derived from a non-human species, such as, but not limited to, cow, pig, horse, cat, dog, rat, mouse, a primate (*e.g.*, a chimpanzee, a monkey such as a cynomolgous monkey). In certain embodiments, one or more components are derived from human and the other components are derived from a mammal other than a human to give rise to chimeric complexes.

30

#### **4.2.2 3' end pre-mRNA endonuclease Complex**

The invention provides a purified protein complex with 3' end pre-mRNA endonuclease

activity comprising two or more of the following: (i) human Sen2 or a functionally active derivative or a functionally active fragment thereof; (ii) human Sen 15 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen34 or a functionally active derivative or a functionally active fragment thereof; (iv) human Sen54 or a functionally active derivative or a functionally active fragment thereof; (v) human Clp1 (ACCESSION NO.:NP\_006822) or a functionally active derivative or a functionally active fragment thereof; (vi) human CPSF160 or a functionally active derivative or a functionally active fragment thereof; (vii) human CPSF30 or a functionally active derivative or a functionally active fragment thereof; (viii) human CstF64 or a functionally active derivative or a functionally active fragment thereof; and/or (ix) human symplekin or a functionally active derivative or a functionally active fragment thereof; (x) human CPSF or a functionally active derivative or a functionally active fragment thereof; (xi) human CFI<sub>m</sub> or a functionally active derivative or a functionally active fragment thereof; (xii) human CFII<sub>m</sub> or a functionally active derivative or a functionally active fragment thereof; and (xiii) human CstF or a functionally active derivative or a functionally active fragment thereof.

In particular, the invention provides a purified protein complex with 3' end pre-mRNA endonuclease activity comprising: (i) human Sen2 or a functionally active derivative or a functionally active fragment thereof; (ii) human Sen 15 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen34 or a functionally active derivative or a functionally active fragment thereof; (iv) human Sen54 or a functionally active derivative or a functionally active fragment thereof; (v) human Clp1 (ACCESSION NO.:NP\_006822) or a functionally active derivative or a functionally active fragment thereof; (vi) human CPSF or a functionally active derivative or a functionally active fragment thereof; (vii) human CFI<sub>m</sub> or a functionally active derivative or a functionally active fragment thereof; (viii) human CFII<sub>m</sub> or a functionally active derivative or a functionally active fragment thereof; and (ix) human CstF or a functionally active derivative or a functionally active fragment thereof.

In one embodiment, the invention provides a purified complex with 3' end pre-mRNA endonuclease activity comprising: (i) human Sen2 (ACCESSION NO.: NP\_079541), or a protein encoded by a nucleic acid that hybridizes to the human Sen2 encoding nucleic acid (ACCESSION NO.: NM\_025265) or its complement under high stringency conditions; (ii) human Sen15 (ACCESSION NO.:NP\_443197), or a protein encoded by a nucleic acid that hybridizes to the human Sen15 encoding nucleic acid (ACCESSION NO.:NM\_052965) or its complement under high stringency conditions; (iii) human Sen34 (ACCESSION

NO.:NP\_076980), or a protein encoded by a nucleic acid that hybridizes to the human Sen34 encoding nucleic acid (ACCESSION NO.:NM\_024075) or its complement under high stringency conditions; (iv) Sen54 (ACCESSION NO.:XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the human Sen54 encoding nucleic acid (ACCESSION NO.:XM\_208944) or its complement under high stringency conditions; and (v) human Clp1 (ACCESSION NO.:NP\_006822) or a protein encoded by a nucleic acid that hybridizes to the human Clp1 encoding nucleic acid (ACCESSION NO.: NM\_006831) or its complement under high stringency conditions. In certain embodiments, the Sen2deltaEx8 complex has RNA-nucleolytic activity. In a specific embodiment the Sen2deltaEx8 complex has tRNA endonuclease and/or 3' end mRNA processing activity. In certain embodiments, the fidelity and accuracy of the tRNA cleavage activity of a Sen2deltaEx8 comprising complex is reduced compared to the the tRNA cleavage activity of full length Sen2 comprising complexes. In certain embodiments, the complex may further comprise: (i) human CPSF160 or a functionally active derivative or a functionally active fragment thereof; (ii) human CPSF30 or a functionally active derivative or a functionally active fragment thereof; (iii) human CstF64 or a functionally active derivative or a functionally active fragment thereof; and/or (iv) human symplekin or a functionally active derivative or a functionally active fragment. In other embodiments, the complexes further comprise (i) human Cleavage-Polyadenylation Specificity Factor ("CPSF") or proteins encoded by nucleic acids that hybridize to human CPSF encoding nucleic acids or their complements under high stringency conditions; (ii) human Cleavage Factor I<sub>m</sub> ("CF I<sub>m</sub>") or proteins encoded by nucleic acids that hybridize to human CFI<sub>m</sub> encoding nucleic acids or their complements under high stringency conditions; (iii) human Cleavage Factor II<sub>m</sub> ("CF II<sub>m</sub>") or proteins encoded by nucleic acids that hybridize to human CFII<sub>m</sub> encoding nucleic acids or their complements under high stringency conditions; and (iv) human Cleavage Stimulation Factor ("CSF") or proteins encoded by nucleic acids that hybridize to human CSF encoding nucleic acids or their complements under high stringency conditions.

The invention provides purified protein complexes having 3' end pre-mRNA endonuclease activity and comprising human Sen2deltaEx8. The invention provides a purified protein complex comprising two or more of the following: (i) human Sen2deltaEx8 or a functionally active derivative thereof; (ii) human Sen54 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen15 or a functionally active derivative or a functionally active fragment thereof; (iv) human Sen34 or a functionally active derivative or a functionally active fragment thereof; and (v) Clp1 or a functionally active derivative or a

functionally active fragment thereof. In particular, the invention provides a purified human Sen2deltaEx8 complex with 3' end pre-mRNA endonuclease activity comprising: (i) human Sen2deltaEx8 or a functionally active derivative thereof; and (ii) human Sen54 or a functionally active derivative or a functionally active fragment thereof. The invention also provides a human  
5 Sen2deltaEx8 complex with 3' end pre-mRNA endonuclease activity comprising: (i) human Sen2deltaEx8 or a functionally active derivative thereof; (ii) human Sen54 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen15 or a functionally active derivative or a functionally active fragment thereof; and (iv) human Sen34 or a functionally active derivative or a functionally active fragment thereof. These human  
10 Sen2deltaEx8 complexes are useful in mapping RNA structure and 3' end pre-mRNA endonuclease processing.

In a specific embodiment, the invention provides a purified human Sen2deltaEx8 complex with 3' end pre-mRNA endonuclease activity comprising: (i) human Sen2deltaEx8 (SEQ ID NO.: 2), or a protein encoded by a nucleic acid that hybridizes to the human  
15 Sen2deltaEx8 encoding nucleic acid (SEQ ID NO.: 1) or its complement under high stringency conditions; and (ii) human Sen15 (ACCESSION NO.:NP\_443197), or a protein encoded by a nucleic acid that hybridizes to the human Sen15 encoding nucleic acid (ACCESSION NO.:NM\_052965) or its complement under high stringency conditions. In another embodiment, the invention provides a purified human Sen2deltaEx8 complex comprising: (i) human  
20 Sen2deltaEx8 (SEQ ID NO.: 2), or a protein encoded by a nucleic acid that hybridizes to the human Sen2deltaEx8 encoding nucleic acid (SEQ ID NO.: 1) or its complement under high stringency conditions; (ii) human Sen15 (ACCESSION NO.:NP\_443197), or a protein encoded by a nucleic acid that hybridizes to the human Sen15 encoding nucleic acid (ACCESSION NO.:NM\_052965) or its complement under high stringency conditions; (iii) human Sen34  
25 (ACCESSION NO.:NP\_076980), or a protein encoded by a nucleic acid that hybridizes to the human Sen34 encoding nucleic acid (ACCESSION NO.:NM\_024075) or its complement under high stringency conditions; and (iv) Sen54 (ACCESSION NO.:XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the human Sen54 encoding nucleic acid (ACCESSION NO.:XM\_208944) or its complement under high stringency conditions. In  
30 accordance with these embodiments, the human Sen2deltaEx8 complex cleaves tRNA at multiple sites. These human Sen2deltaEx8 complexes are useful in mapping RNA structure and 3' endonuclease processing.

The invention provides a purified human Sen2deltaEx8 complex with 3' end pre-mRNA



endonuclease activity comprising: (i) human Sen2deltaEx8 or a functionally active derivative thereof; (ii) human Sen54 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen15 or a functionally active derivative or a functionally active fragment thereof; (iv) human Sen34 or a functionally active derivative or a functionally active fragment thereof; and (v) human Clp1 (ACCESSION NO.:NP\_006822) or a functionally active derivative or a functionally active fragment thereof. In certain embodiments, the Sen2deltaEx8 complex has RNA-nucleolytic activity. In a specific embodiment the Sen2deltaEx8 complex has tRNA endonuclease and/or 3' end mRNA processing activity. In certain embodiments, the fidelity and accuracy of the tRNA cleavage activity of a Sen2deltaEx8 comprising complex is reduced compared to the the tRNA cleavage activity of full length Sen2 comprising complexes. In certain embodiments, the complex may further comprise: (i) human CPSF160 or a functionally active derivative or a functionally active fragment thereof; (ii) human CPSF30 or a functionally active derivative or a functionally active fragment thereof; (iii) human CstF64 or a functionally active derivative or a functionally active fragment thereof; and/or (iv) human symplekin or a functionally active derivative or a functionally active fragment.

The invention also provides a purified human Sen2deltaEx8 complex with 3' end pre-mRNA endonuclease activity comprising: (i) human Sen2deltaEx8 or a functionally active derivative thereof; (ii) human Sen54 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen15 or a functionally active derivative or a functionally active fragment thereof; (iv) human Sen34 or a functionally active derivative or a functionally active fragment thereof; (v) human Clp1 (ACCESSION NO.:NP\_006822) or a functionally active derivative or a functionally active fragment thereof; (vi) human CSPF or a functionally active derivative or a functionally active fragment thereof; (vii) human CFI<sub>m</sub> or a functionally active derivative or a functionally active fragment thereof; (viii) human CFII<sub>m</sub> or a functionally active derivative or a functionally active fragment thereof; and (ix) human CstF or a functionally active derivative or a functionally active fragment thereof.

In a specific embodiment, the invention provides a purified human Sen2deltaEx8 complex with 3' end pre-mRNA endonuclease activity comprising: (i) human Sen2deltaEx8 (SEQ ID NO.: 2), or a protein encoded by a nucleic acid that hybridizes to the human Sen2deltaEx8 encoding nucleic acid (SEQ ID NO.: 1) or its complement under high stringency conditions; (ii) human Sen54 (ACCESSION NO.:XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the human Sen54 encoding nucleic acid (ACCESSION NO.:XM\_208944) or its complement under high stringency conditions; (iii) human Sen15

- (ACCESSION NO.:NP\_443197), or a protein encoded by a nucleic acid that hybridizes to the human Sen15 encoding nucleic acid (ACCESSION NO.:NM\_052965) or its complement under high stringency conditions; (iv) human Sen34 (ACCESSION NO.:NP\_076980), or a protein encoded by a nucleic acid that hybridizes to the human Sen34 encoding nucleic acid
- 5 (ACCESSION NO.:NM\_024075) or its complement under high stringency conditions; and (v) human Clp1 (ACCESSION NO.:NP\_006822) or a protein encoded by a nucleic acid that hybridizes to the human Clp1 encoding nucleic acid (ACCESSION NO.:NM\_006831) or its complement under high stringency conditions. In certain embodiments, the complex may further comprise: (i) human CPSF160 or a protein encoded by a nucleic acid that hybridizes to
- 10 the human CPSF160 encoding nucleic acid; (ii) human CPSF30 or a protein encoded by a nucleic acid that hybridizes to the human CPSF30 encoding nucleic acid; (iii) human CstF64 or a protein encoded by a nucleic acid that hybridizes to the human CstF64 encoding nucleic acid; and/or (iv) human symplekin or a protein encoded by a nucleic acid that hybridizes to the human symplekin encoding nucleic acid.
- 15 In another embodiment, the invention provides a purified human Sen2deltaEx8 complex with 3' end pre-mRNA endonuclease activity comprising: (i) human Sen2deltaEx8 (SEQ ID NO.: 2), or a protein encoded by a nucleic acid that hybridizes to the human Sen2deltaEx8 encoding nucleic acid (SEQ ID NO.: 1) or its complement under high stringency conditions; (ii) human Sen54 (ACCESSION NO.:XP\_208944), or a protein encoded by a nucleic acid that
- 20 hybridizes to the human Sen54 encoding nucleic acid (ACCESSION NO.:XM\_208944) or its complement under high stringency conditions; (iii) human Sen15 (ACCESSION NO.:NP\_443197), or a protein encoded by a nucleic acid that hybridizes to the human Sen15 encoding nucleic acid (ACCESSION NO.:NM\_052965) or its complement under high stringency conditions; (iv) human Sen34 (ACCESSION NO.:NP\_076980), or a protein encoded
- 25 by a nucleic acid that hybridizes to the human Sen34 encoding nucleic acid (ACCESSION NO.:NM\_024075) or its complement under high stringency conditions; (v) human Clp1 (ACCESSION NO.:NP\_006822) or a protein encoded by a nucleic acid that hybridizes to the human Clp1 encoding nucleic acid (ACCESSION NO.:NM\_006831) or its complement under high stringency conditions; (vi) a human CPSF (see Table 1 for accession numbers of
- 30 components), or proteins encoded by nucleic acids that hybridize to the human CPSF encoding nucleic acids or their complements under high stringency conditions; (vii) a human CFI<sub>m</sub> (see Table 1 for accession numbers of components), or proteins encoded by nucleic acids that hybridize to the human CFI<sub>m</sub> encoding nucleic acids or their complements under high stringency

conditions; (viii) a human CFII<sub>m</sub> (see Table 1 for accession numbers of components), or proteins encoded by nucleic acids that hybridize to the human CFII<sub>m</sub> encoding nucleic acids or their complements under high stringency conditions; and (ix) human CstF (see Table 1 for accession numbers of components), or proteins encoded by nucleic acids that hybridize to the human CstF encoding nucleic acids or their complements under high stringency conditions.

The invention provides a purified human Sen2deltaEx8 complex with 3' end pre-mRNA endonuclease activity comprising: (i) human Sen2deltaEx8 or a functionally active derivative thereof; (ii) human Sen54 or a functionally active derivative or a functionally active fragment thereof; and (iii) human Clp1 (ACCESSION NO.:NP\_006822) or a functionally active derivative or a functionally active fragment thereof. In certain embodiments, the Sen2deltaEx8 complex has RNA-nucleolytic activity. In a specific embodiment the Sen2deltaEx8 complex has tRNA endonuclease and/or 3' end mRNA processing activity. In certain embodiments, the fidelity and accuracy of the tRNA cleavage activity of a Sen2deltaEx8 comprising complex is reduced compared to the the tRNA cleavage activity of full length Sen2 comprising complexes.

In certain embodiments, the complex may further comprise: (i) human CPSF160 or a functionally active derivative or a functionally active fragment thereof; (ii) human CPSF30 or a functionally active derivative or a functionally active fragment thereof; (iii) human CstF64 or a functionally active derivative or a functionally active fragment thereof; and/or (iv) human symplekin or a functionally active derivative or a functionally active fragment.

In other embodiments, the purified complex further comprises (i) human CPSF or a functionally active derivative or a functionally active fragment thereof; (ii) human CFI<sub>m</sub> or a functionally active derivative or a functionally active fragment thereof; (iii) human CFII<sub>m</sub> or a functionally active derivative or a functionally active fragment thereof; and (iv) human CstF or a functionally active derivative or a functionally active fragment thereof.

In a specific embodiment, the invention provides a purified Sen2deltaEx8 complex with 3' end pre-mRNA endonuclease activity comprising: (i) human Sen2deltaEx8 (SEQ ID NO.: 2), or a protein encoded by a nucleic acid that hybridizes to the human Sen2deltaEx8 encoding nucleic acid (SEQ ID NO.: 1) or its complement under high stringency conditions; (ii) human Sen54 (ACCESSION NO.:XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the human Sen54 encoding nucleic acid (ACCESSION NO.:XM\_208944) or its complement under high stringency conditions; and (iii) human Clp1 (ACCESSION NO.:NP\_006822) or a protein encoded by a nucleic acid that hybridizes to the human Clp1 encoding nucleic acid (ACCESSION NO.: NM\_006831) or its complement under high stringency conditions.

In certain embodiments, the Sen2deltaEx8 complex has RNA-nucleolytic activity. In a specific embodiment the Sen2deltaEx8 complex has tRNA endonuclease and/or 3' end mRNA processing activity. In certain embodiments, the fidelity and accuracy of the tRNA cleavage activity of a Sen2deltaEx8 comprising complex is reduced compared to the the tRNA cleavage activity of full length Sen2 comprising complexes. In certain embodiments, the complex may further comprise: (i) human CPSF160 or a protein encoded by a nucleic acid that hybridizes under stringent conditions to a CPSF160 encoding nucleic acid; (ii) human CPSF30 or a protein encoded by a nucleic acid that hybridizes under stringent conditions to a CPSF30 encoding nucleic acid; (iii) human CstF64 or a protein encoded by a nucleic acid that hybridizes under stringent conditions to a CstF60 encoding nucleic acid; and/or (iv) human symplekin or a protein encoded by a nucleic acid that hybridizes under stringent conditions to a symplekin encoding nucleic acid.

In another embodiment, the invention provides a purified Sen2deltaEx8 complex with 3' end pre-mRNA endonuclease activity comprising: (i) human Sen2deltaEx8 (SEQ ID NO.: 2), or a protein encoded by a nucleic acid that hybridizes to the human Sen2deltaEx8 encoding nucleic acid (SEQ ID NO.: 1) or its complement under high stringency conditions; (ii) human Sen54 (ACCESSION NO.:XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the human Sen54 encoding nucleic acid (ACCESSION NO.:XM\_208944) or its complement under high stringency conditions; (iii) human Clp1 (ACCESSION NO.:NP\_006822) or a protein encoded by a nucleic acid that hybridizes to the human Clp1 encoding nucleic acid (ACCESSION NO.: NM\_006831) or its complement under high stringency conditions; (iv) human CPSF or proteins encoded by nucleic acids that hybridize to the human CPSF encoding nucleic acids or their complements under high stringency conditions; (v) human CFI<sub>m</sub> or proteins encoded by nucleic acids that hybridize to the human CFI<sub>m</sub> encoding nucleic acids or their complements under high stringency conditions; (vi) human CF II<sub>m</sub> or proteins encoded by nucleic acids that hybridize to the human CFII<sub>m</sub> encoding nucleic acids or their complements under high stringency conditions; and (vii) human CstF or proteins encoded by nucleic acids that hybridize to the human CstF encoding nucleic acids or their complements under high stringency conditions.

CPSF, CstF, CFI<sub>m</sub> and CFII<sub>m</sub> consist of multiple subunits. The accession numbers of the different subunits are set forth in Table 1 in section 4.2.1. CPSF, CstF, CFI<sub>m</sub> and CFII<sub>m</sub> can each comprise a different set of subunits. In a specific embodiment, CPSF comprises the 160 kD factor 1 and the 30 kD factor 4. In a more specific embodiment, CPSF comprises the 160

kD factor 1, the 100 kD factor 2, the 73 kD factor 3, and the 30 kD factor 4. In a specific embodiment, CstF comprises the 50 kD subunit 1, the 64 kD subunit 2, and the 77 kD subunit 3. In a more specific embodiment, CstF comprises the 50 kD subunit 1, the 64 kD subunit 2, the 77 kD subunit 3, and symplekin. In a specific embodiment, CFIm comprises the 68 kD subunit and the 25 kD subunit. In a more specific embodiment, CFIm comprises the 68 kD subunit, the 25 kD subunit, the 59 kD subunit, and the 72 kD subunit. In a specific embodiment, CFIIIm comprises Clp1. In a more specific embodiment, CFIIIm comprises Clp1 and hPcf11. In another more specific embodiment, CFIIIm comprises ClpI, the CFIm 25 kD subunit and the CFIm 68 kD subunit. In even another more specific embodiment, CFIIIm comprises ClpI, the CFIm 25 kD subunit and the CFIm 68 kD subunit and hpcf11.

Detailed information on Symplekin can be obtained from the homepage of Dr. Keller's laboratory at the biocentre of the University of Basel and in Takagaki, Y. and J. Manley, 2000, *Molecular & Cellular Biol* 20:1515-1525.

Wahle and Ruegsegger, 1999, *FEMS Micro Rev.*, 23, 277-295 and Zhao et al., 1999, *Micoboi. Mol. Biol. Rev.*, 63, 405-445 describe factors involved RNA processing, both references are incorporated herein in their entireties.

In certain embodiments, all subunits of CPSF and CstF, respectively, are present in a complex of the invention.

In certain embodiments, the invention provides complexes wherein the components are homologs or analogs of the human components of the protein complexes of the invention. Homologs or analogs of the human components of a complex of the invention are at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 98%, at least 99% or at least 99.5% identical to a human component of a complex of the invention. Derivatives can be, e.g., fusion proteins, mutant forms of the protein, or forms of the protein with chemical moieties linked to the protein. A fragment of a component of a complex of the invention is a portion of the protein component that maintains the ability of the component to be physically integrated into the complex.

In certain embodiments, the protein components of a complex of the invention are derived from the same species. In more specific embodiments, the protein components are all derived from human. In another specific embodiment, the protein components are all derived from a mammal.

In certain other embodiments, the protein components of a complex of the invention are derived from a non-human species, such as, but not limited to, cow, pig, horse, cat, dog, rat,

mouse, a primate (*e.g.*, a chimpanzee, a monkey such as a cynomolgous monkey). In certain embodiments, one or more components are derived from human and the other components are derived from a mammal other than a human to give rise to chimeric complexes.

#### 5                    **4.2.3 tRNA Cleavage Complex**

The invention provides Sen2deltaEx8 complexes with pre-tRNA cleavage activity. The invention provides a purified protein complex with pre-tRNA cleavage activity comprising two or more of the following: (i) human Sen2deltaEx8 or a functionally active derivative thereof; (ii) human Sen54 or a functionally active derivative or a functionally active fragment thereof; 10 (iii) human Sen15 or a functionally active derivative or a functionally active fragment thereof; (iv) human Sen34 or a functionally active derivative or a functionally active fragment thereof; and (v) Clp1 or a functionally active derivative or a functionally active fragment thereof.

In certain embodiments, the invention provides complexes comprising two or more of the following: (i) human Sen2deltaEx8 (SEQ ID NO.: 2), or a protein encoded by a nucleic acid 15 that hybridizes to the human Sen2deltaEx8 encoding nucleic acid (SEQ ID NO.: 1) or its complement under high stringency conditions; (ii) human Sen15 (ACCESSION NO.:NP\_443197), or a protein encoded by a nucleic acid that hybridizes to the human Sen15 encoding nucleic acid (ACCESSION NO.:NM\_052965) or its complement under high stringency conditions; (iii) human Sen34 (ACCESSION NO.:NP\_076980), or a protein encoded 20 by a nucleic acid that hybridizes to the human Sen34 encoding nucleic acid (ACCESSION NO.:NM\_024075) or its complement under high stringency conditions; and (iv) human Sen54 (ACCESSION NO.:XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the human Sen54 encoding nucleic acid (ACCESSION NO.:XM\_208944) or its complement under high stringency conditions.

25                    The invention provides a purified human Sen2deltaEx8 complex with pre-tRNA cleavage activity comprising: (i) human Sen2deltaEx8 or a functionally active derivative thereof; and (ii) human Sen54 or a functionally active derivative or a functionally active fragment thereof. The invention also provides a human Sen2deltaEx8 complex with pre-tRNA cleavage activity comprising: (i) human Sen2deltaEx8 or a functionally active derivative 30 thereof; (ii) human Sen54 or a functionally active derivative or a functionally active fragment thereof; (iii) human Sen15 or a functionally active derivative or a functionally active fragment thereof; and (iv) human Sen34 or a functionally active derivative or a functionally active

fragment thereof. These human Sen2deltaEx8 complexes cleave tRNA at multiple sites and are useful in mapping RNA structure and 3' end endonuclease processing.

In a specific embodiment, the invention provides a purified human Sen2deltaEx8 complex with pre-tRNA cleavage activity comprising: (i) human Sen2deltaEx8 (SEQ ID NO.: 2), or a protein encoded by a nucleic acid that hybridizes to the human Sen2deltaEx8 encoding nucleic acid (SEQ ID NO.: 1) or its complement under high stringency conditions; and (ii) human Sen15 (ACCESSION NO.:NP\_443197), or a protein encoded by a nucleic acid that hybridizes to the human Sen15 encoding nucleic acid (ACCESSION NO.:NM\_052965) or its complement under high stringency conditions. In another embodiment, the invention provides a purified human Sen2deltaEx8 complex comprising: (i) human Sen2deltaEx8 (SEQ ID NO.: 2), or a protein encoded by a nucleic acid that hybridizes to the human Sen2deltaEx8 encoding nucleic acid (SEQ ID NO.: 1) or its complement under high stringency conditions; (ii) human Sen15 (ACCESSION NO.:NP\_443197), or a protein encoded by a nucleic acid that hybridizes to the human Sen15 encoding nucleic acid (ACCESSION NO.:NM\_052965) or its complement under high stringency conditions; (iii) human Sen34 (ACCESSION NO.:NP\_076980), or a protein encoded by a nucleic acid that hybridizes to the human Sen34 encoding nucleic acid (ACCESSION NO.:NM\_024075) or its complement under high stringency conditions; and (iv) Sen54 (ACCESSION NO.:XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the human Sen54 encoding nucleic acid (ACCESSION NO.:XM\_208944) or its complement under high stringency conditions. In certain embodiments, the Sen2deltaEx8 complex has RNA-nucleolytic activity. In a specific embodiment the Sen2deltaEx8 complex has tRNA endonuclease and/or 3' end mRNA processing activity. In certain embodiments, the fidelity and accuracy of the tRNA cleavage activity of a Sen2deltaEx8 comprising complex is reduced compared to the the tRNA cleavage activity of full length Sen2 comprising complexes. In certain embodiments, the complex may further comprise: (i) human CPSF160 or a protein encoded by a nucleic acid that hybridizes under stringent conditions to a CPSF160 encoding nucleic acid; (ii) human CPSF30 or a protein encoded by a nucleic acid that hybridizes under stringent conditions to a CPSF30 encoding nucleic acid; (iii) human CstF64 or a protein encoded by a nucleic acid that hybridizes under stringent conditions to a CstF64 encoding nucleic acid; and/or (iv) human symplekin or a protein encoded by a nucleic acid that hybridizes under stringent conditions to a symplekin encoding nucleic acid. In accordance with these embodiments, the human Sen2deltaEx8 complex cleaves tRNA at multiple sites. These human Sen2deltaEx8 complexes are useful in mapping RNA structure and 3' endonuclease processing.

In certain embodiments, the invention provides complexes wherein the components are homologs or analogs of the human components of the protein complexes of the invention. Homologs or analogs of the human components of a complex of the invention are at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 98%, at least 99% or at least 99.5% identical to a human component of a complex of the invention. Derivatives can be, e.g., fusion proteins, mutant forms of the protein, or forms of the protein with chemical moieties linked to the protein. A fragment of a component of a complex of the invention is a portion of the protein component that maintains the ability of the component to be physically integrated into the complex.

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#### **4.2.4 Ribosomal RNA Cleavage Complex**

The invention also provides protein complexes with pre-ribosomal RNA cleavage activity. In particular, the invention provides a protein complex with pre-ribosomal RNA cleavage activity comprising: (i) human Sen15 or a functionally active derivative or a functionally active fragment thereof; and (ii) human Sen34 or a functionally active derivative or a functionally active fragment thereof. This protein complex may be used in the biogenesis of different ribosomal RNAs. For example, the production of 28S, 18S, 5.5S and 5S ribosomal RNA may be altered by modulating this protein complex.

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In particular, the invention provides a complex with pre-ribosomal RNA cleavage activity, wherein the complex comprises: human Sen34 (ACCESSION NO.:NP\_076980), or a protein encoded by a nucleic acid that hybridizes to the human Sen34 encoding nucleic acid (ACCESSION NO.:NM\_024075) or its complement under high stringency conditions; and human Sen15 (ACCESSION NO.:NP\_443197), or a protein encoded by a nucleic acid that hybridizes to the human Sen15 encoding nucleic acid (ACCESSION NO.:NM\_052965) or its complement under high stringency conditions.

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In certain embodiments, the invention provides complexes wherein the components are homologs or analogs of the human components of the protein complexes of the invention. Homologs or analogs of the human components of a complex of the invention are at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 98%, at least 99% or at least 99.5% identical to a human component of a complex of the invention. Derivatives can be, e.g., fusion proteins, mutant forms of the protein, or forms of the protein with chemical moieties linked to the protein. A

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fragment of a component of a complex of the invention is a portion of the protein component that maintains the ability of the component to be physically integrated into the complex.

In certain embodiments, the protein components of a complex of the invention are derived from the same species. In more specific embodiments, the protein components are all derived from human. In another specific embodiment, the protein components are all derived from a mammal.

In certain other embodiments, the protein components of a complex of the invention are derived from a non-human species, such as, but not limited to, cow, pig, horse, cat, dog, rat, mouse, a primate (*e.g.*, a chimpanzee, a monkey such as a cynomolgous monkey). In certain embodiments, one or more components are derived from human and the other components are derived from a mammal other than a human to give rise to chimeric complexes.

#### **4.3 Generation and Purification of Complexes of the Invention**

The complexes of the invention can be generated by any method known to the skilled artisan. In certain embodiments, the complexes can be generated by co-expressing the components of the complex in a cell and subsequently purifying the complex. In certain, more specific embodiments, the cell expresses at least one component of the complex by recombinant DNA technology. In other embodiments, the cells normally express the components of the complex. In certain other embodiments, the components of the complex are expressed separately, wherein the components can be expressed using recombinant DNA technology or wherein at least one component is purified from a cell that normally expresses the component. The individual components of the complex are incubated *in vitro* under conditions conducive to the binding of the components of a complex of the invention to each other to generate a complex of the invention.

If one or more of the components is expressed by recombinant DNA technology, any method known to the skilled artisan can be used to produce the recombinant protein. The nucleic and amino acid sequences of the component proteins of the protein complexes of the present invention are provided herein (see Table 1; and SEQ ID NOs: 1-2), and can be obtained by any method known in the art, *e.g.*, by PCR amplification using synthetic primers hybridizable to the 3' and 5' ends of each sequence, and/or by cloning from a cDNA or genomic library using an oligonucleotide specific for each nucleotide sequence.

The protein components, either alone or in a complex, can be obtained by methods well known in the art for protein purification and recombinant protein expression. For recombinant expression of one or more of the proteins, the nucleic acid containing all or a portion of the nucleotide sequence encoding the protein can be inserted into an appropriate expression vector, 5 *i.e.*, a vector that contains the necessary elements for the transcription and translation of the inserted protein coding sequence. The necessary transcriptional and translational signals can also be supplied by the native promoter of the component protein gene, and/or flanking regions.

A variety of host-vector systems may be utilized to express the protein coding sequence. These include but are not limited to mammalian cell systems infected with virus (*e.g.*, vaccinia virus, adenovirus, etc.); insect cell systems infected with virus (*e.g.*, baculovirus); 10 microorganisms such as yeast containing yeast vectors; or bacteria transformed with bacteriophage, DNA, plasmid DNA, or cosmid DNA. The expression elements of vectors vary in their strengths and specificities. Depending on the host-vector system utilized, any one of a number of suitable transcription and translation elements may be used.

15 In a preferred embodiment, a complex of the present invention is obtained by expressing the entire coding sequences of the component proteins in the same cell, either under the control of the same promoter or separate promoters. In yet another embodiment, a derivative, fragment or homolog of a component protein is recombinantly expressed. Preferably the derivative, fragment or homolog of the protein forms a complex with the other components of the complex. 20 In a specific embodiment, the protein components form a complex that binds to an anti-complex antibody.

Any method available in the art can be used for the insertion of DNA fragments into a vector to construct expression vectors containing a chimeric gene consisting of appropriate transcriptional/translational control signals and protein coding sequences. These methods may 25 include *in vitro* recombinant DNA and synthetic techniques and *in vivo* recombinant techniques (genetic recombination). Expression of nucleic acid sequences encoding a component protein, or a derivative, fragment or homolog thereof, may be regulated by a second nucleic acid sequence so that the gene or fragment thereof is expressed in a host transformed with the recombinant DNA molecule(s). For example, expression of the proteins may be controlled by 30 any promoter/enhancer known in the art. In a specific embodiment, the promoter is not native to the genes for the component protein. In certain embodiments, a promoter that may be used is a constitutive promoter. In certain embodiments, a promoter that may be used is an inducible promoter. In certain embodiments, a promoter that may be used is a tissue-specific promoter.

Promoters that may be used include but are not limited to the SV40 early promoter (Bernoist and Chambon, 1981, *Nature* 290:304-310), the promoter contained in the 3' long terminal repeat of Rous sarcoma virus (Yamamoto et al., 1980, *Cell* 22:787-797), the herpes thymidine kinase promoter (Wagner et al., 1981, *Proc. Natl. Acad. Sci. USA* 78:1441-1445), the regulatory  
5 sequences of the metallothionein gene (Brinster et al., 1982, *Nature* 296:39-42); prokaryotic expression vectors such as the  $\beta$ -lactamase promoter (Villa-Kamaroff et al., 1978, *Proc. Natl. Acad. Sci. USA* 75:3727-3731) or the tac promoter (DeBoer et al., 1983, *Proc. Natl. Acad. Sci. USA* 80:21-25; Gilbert et al., 1980, *Scientific American* 242:79-94); plant expression vectors comprising the nopaline synthetase promoter (Herrar-Estrella et al., 1984, *Nature* 303:209-213)  
10 or the cauliflower mosaic virus 35S RNA promoter (Gardner et al., 1981, *Nucleic Acids Res.* 9:2871), and the promoter of the photosynthetic enzyme ribulose biphosphate carboxylase (Herrera-Estrella et al., 1984, *Nature* 310:115-120); promoter elements from yeast and other fungi such as the Gal4 promoter (Johnston et al., 1987, *Microbiol. Rev.* 51:458-476), the alcohol dehydrogenase promoter (Schibler et al., 1987, *Annual Review Genetics* 21:237-257), the  
15 phosphoglycerol kinase promoter (Struhl et al., 1995, *Annual Review Genetics* 29:651-674-257; Guarente 1987, *Annual Review Genetics* 21:425-452), the alkaline phosphatase promoter (Struhl et al., 1995, *Annual Review Genetics* 29:651-674-257; Guarente 1987, *Annual Review Genetics* 21:425-452), and the following animal transcriptional control regions that exhibit tissue specificity and have been utilized in transgenic animals: elastase I gene control region  
20 which is active in pancreatic acinar cells (Swift et al., 1984, *Cell* 38:639-646; Ornitz et al., 1986, *Cold Spring Harbor Symp. Quant. Biol.* 50:399-409; MacDonald 1987, *Hepatology* 7:425-515); insulin gene control region which is active in pancreatic beta cells (Hanahan et al., 1985, *Nature* 315:115-122), immunoglobulin gene control region which is active in lymphoid cells (Grosschedl et al., 1984, *Cell* 38:647-658; Adams et al., 1985, *Nature* 318:533-538; Alexander  
25 et al., 1987, *Mol. Cell Biol.* 7:1436-1444), mouse mammary tumor virus control region which is active in testicular, breast, lymphoid and mast cells (Leder et al., 1986, *Cell* 45:485-495), albumin gene control region which is active in liver (Pinckert et al., 1987, *Genes and Devel.* 1:268-276), alpha-fetoprotein gene control region which is active in liver (Krumlauf et al., 1985, *Mol. Cell. Biol.* 5:1639-1648; Hammer et al., 1987, *Science* 235:53-58), alpha-1 antitrypsin  
30 gene control region which is active in liver (Kelsey et al., 1987, *Genes and Devel.* 1:161-171), beta globin gene control region which is active in myeloid cells (Mogam et al., 1985, *Nature* 315:338-340; Kollias et al., 1986, *Cell* 46:89-94), myelin basic protein gene control region which is active in oligodendrocyte cells of the brain (Readhead et al., 1987, *Cell* 48:703-712),

myosin light chain-2 gene control region which is active in skeletal muscle (Sani 1985, Nature 314:283-286), and gonadotrophic releasing hormone gene control region which is active in gonadotrophs of the hypothalamus (Mason et al., 1986, Science 234:1372-1378).

5 In a specific embodiment, a vector is used that comprises a promoter operably linked to nucleic acid sequences encoding a component protein, or a fragment, derivative or homolog thereof, one or more origins of replication, and optionally, one or more selectable markers (*e.g.*, an antibiotic resistance gene). In accordance with this embodiment, a promoter can be any promoter known to the skilled artisan. The promoter can be, but is not limited to be, a constitutive promoter, a tissue-specific promoter or an inducible promoter.

10 In another specific embodiment, an expression vector containing the coding sequence, or a portion thereof, of a component protein, either together or separately, is made by subcloning the gene sequences into the multiple cloning site of one of the three pGEX vectors (glutathione S-transferase expression vectors; Smith and Johnson, 1988, Gene 7:31-40). Care should be taken that the nucleotide sequence encoding the protein component is in the same reading frame  
15 as the nucleotide sequence encoding the GST such that the protein component and the GST are expressed as one fusion protein.

Expression vectors containing the sequences of interest can be identified by three general approaches: (1) nucleic acid hybridization, (2) presence or absence of "marker" gene function, and (3) expression of the inserted sequences. In the first approach, coding sequences can be  
20 detected by nucleic acid hybridization to probes comprising sequences homologous and complementary to the inserted sequences. In the second approach, the recombinant vector/host system can be identified and selected based upon the presence or absence of certain "marker" functions (*e.g.*, resistance to antibiotics, occlusion body formation in baculovirus, etc.) caused by insertion of the sequences of interest in the vector. For example, if a component protein  
25 gene, or portion thereof, is inserted within the marker gene sequence of the vector, recombinants containing the encoded protein or portion will be identified by the absence of the marker gene function (*e.g.*, loss of beta-galactosidase activity). In the third approach, recombinant expression vectors can be identified by assaying for the component protein expressed by the recombinant vector. Such assays can be based, for example, on the physical or functional properties of the  
30 interacting species in *in vitro* assay systems, *e.g.*, formation of a complex comprising the protein or binding to an anti-complex antibody. The expressed sequences can be detected using antibodies that are specifically directed to the expressed protein component. In certain

embodiments, the expressed sequence is a fusion protein of the protein component and comprises a peptide tag, wherein the peptide tag can be visualized, such as a GFP tag.

Once recombinant component protein molecules are identified and the complexes or individual proteins purified, several methods known in the art can be used to propagate them.

5 Using a suitable host system and growth conditions, recombinant expression vectors can be propagated and amplified in quantity. As previously described, the expression vectors or derivatives which can be used include, but are not limited to, human or animal viruses such as vaccinia virus or adenovirus; insect viruses such as baculovirus, yeast vectors; bacteriophage vectors such as lambda phage; and plasmid and cosmid vectors.

10 In addition, a host cell strain may be chosen that modulates the expression of the inserted sequences, or modifies or processes the expressed proteins in the specific fashion desired. Expression from certain promoters can be elevated in the presence of certain inducers; thus expression of the genetically-engineered component proteins may be controlled. Furthermore, different host cells have characteristic and specific mechanisms for the translational and post-  
15 translational processing and modification (*e.g.*, glycosylation, phosphorylation, etc.) of proteins. Appropriate cell lines or host systems can be chosen to ensure that the desired modification and processing of the foreign protein is achieved. For example, expression in a bacterial system can be used to produce an unglycosylated core protein, while expression in mammalian cells ensures “native” glycosylation of a heterologous protein. Furthermore, different vector/host expression  
20 systems may effect processing reactions to different extents.

In other specific embodiments, a component protein or a fragment, homolog or derivative thereof, may be expressed as fusion or chimeric protein product comprising the protein, fragment, homolog, or derivative joined via a peptide bond to a heterologous protein sequence. Such chimeric products can be made by ligating the appropriate nucleic acid  
25 sequences encoding the desired amino acids to each other by methods known in the art, in the proper coding frame, and expressing the chimeric products in a suitable host by methods commonly known in the art. Alternatively, such a chimeric product can be made by protein synthetic techniques, *e.g.*, by use of a peptide synthesizer. Chimeric genes comprising a portion of a component protein fused to any heterologous protein-encoding sequences may be  
30 constructed.

In a specific embodiment, fusion proteins are provided that contain the interacting domains of the component proteins and, optionally, a peptide linker between the two domains, where such a linker promotes the interaction of the binding domains. These fusion proteins may

be particularly useful where the stability of the interaction is desirable (due to the formation of the complex as an intra-molecular reaction), for example, in production of antibodies specific to the complex.

In particular, protein component derivatives can be made by altering their sequences by  
5 substitutions, additions or deletions that provide for functionally equivalent molecules. Due to the degeneracy of nucleotide coding sequences, other DNA sequences that encode substantially the same amino acid sequence as a component gene or cDNA can be used in the practice of the present invention. These include but are not limited to nucleotide sequences comprising all or portions of the component protein gene that are altered by the substitution of different codons  
10 that encode a functionally equivalent amino acid residue within the sequence, thus producing a silent change. Likewise, the derivatives of the invention include, but are not limited to, those containing, as a primary amino acid sequence, all or part of the amino acid sequence of a component protein, including altered sequences in which functionally equivalent amino acid residues are substituted for residues within the sequence resulting in a silent change. For  
15 example, one or more amino acid residues within the sequence can be substituted by another amino acid of a similar polarity that acts as a functional equivalent, resulting in a silent alteration. Substitutes for an amino acid within the sequence may be selected from other members of the class to which the amino acid belongs. For example, the nonpolar (hydrophobic) amino acids include alanine, leucine, isoleucine, valine, proline, phenylalanine,  
20 tryptophan and methionine. The polar neutral amino acids include glycine, serine, threonine, cysteine, tyrosine, asparagine, and glutamine. The positively charged (basic) amino acids include arginine, lysine and histidine. The negatively charged (acidic) amino acids include aspartic acid and glutamic acid.

The protein component derivatives and analogs of the invention can be produced by  
25 various methods known in the art. The manipulations which result in their production can occur at the gene or protein level. For example, the cloned gene sequences can be modified by any of numerous strategies known in the art (Sambrook et al., 1989, Molecular Cloning, A Laboratory Manual, 2d Ed., Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York). The sequences can be cleaved at appropriate sites with restriction endonuclease(s), followed by  
30 further enzymatic modification if desired, isolated, and ligated in vitro. In the production of the gene encoding a derivative, homolog or analog of a component protein, care should be taken to ensure that the modified gene retains the original translational reading frame, uninterrupted by translational stop signals, in the gene region where the desired activity is encoded.

Additionally, the encoding nucleic acid sequence can be mutated *in vitro* or *in vivo*, to create and/or destroy translation, initiation, and/or termination sequences, or to create variations in coding regions and/or form new restriction endonuclease sites or destroy pre-existing ones, to facilitate further *in vitro* modification. Any technique for mutagenesis known in the art can be used, including but not limited to, chemical mutagenesis and *in vitro* site-directed mutagenesis (Hutchinson et al., 1978, J. Biol. Chem 253:6551-6558), amplification with PCR primers containing a mutation, use of chimeric oligonucleotides, etc.

Once a recombinant cell expressing a component protein, or fragment or derivative thereof, is identified, the individual gene product or complex can be purified and analyzed. This is achieved by assays based on the physical and/or functional properties of the protein or complex, including, but not limited to, radioactive labeling of the product followed by analysis by gel electrophoresis, immunoassay, cross-linking to marker-labeled product, etc.

The component proteins and complexes may be purified by standard methods known in the art (either from natural sources or recombinant host cells expressing the complexes or proteins), including but not restricted to column chromatography (*e.g.*, ion exchange, affinity, gel exclusion, reversed-phase high pressure, fast protein liquid, etc.), differential centrifugation, differential solubility, or by any other standard technique used for the purification of proteins. Functional properties may be evaluated using any suitable assay known in the art. For a more detailed description of purification procedures of the components and the complexes of the invention, see below.

Alternatively, once a component protein or its derivative, is identified, the amino acid sequence of the protein can be deduced from the nucleic acid sequence of the chimeric gene from which it was encoded. As a result, the protein or its derivative can be synthesized by standard chemical methods known in the art (*e.g.*, Hunkapiller et al., 1984, Nature 310: 105-111).

Manipulations of component protein sequences may be made at the protein level. Included within the scope of the invention is a complex in which the component proteins or derivatives and analogs that are differentially modified during or after translation, *e.g.*, by glycosylation, acetylation, phosphorylation, amidation, derivatization by known protecting/blocking groups, proteolytic cleavage, linkage to an antibody molecule or other cellular ligand, etc. Any of numerous chemical modifications may be carried out by known techniques, including but not limited to specific chemical cleavage by cyanogen bromide,

trypsin, chymotrypsin, papain, V8 protease,  $\text{NaBH}_4$ , acetylation, formylation, oxidation, reduction, metabolic synthesis in the presence of tunicamycin, etc.

In specific embodiments, the amino acid sequences are modified to include a fluorescent label. In another specific embodiment, the protein sequences are modified to have a  
5 heterofunctional reagent; such heterofunctional reagents can be used to crosslink the members of the complex.

In addition, complexes of analogs and derivatives of component proteins can be chemically synthesized. For example, a peptide corresponding to a portion of a component protein, which comprises the desired domain or mediates the desired activity *in vitro* (e.g.,  
10 complex formation) can be synthesized by use of a peptide synthesizer. Furthermore, if desired, non-classical amino acids or chemical amino acid analogs can be introduced as a substitution or addition into the protein sequence. Non-classical amino acids include but are not limited to the D-isomers of the common amino acids,  $\alpha$ -amino isobutyric acid, 4-aminobutyric acid (4-Abu), 2-aminobutyric acid (2- Abu), 6-amino hexanoic acid (Ahx), 2-amino isobutyric acid (2-Aib),  
15 3-amino propionic acid, ornithine, norleucine, norvaline, hydroxyproline, sarcosine, citrulline, cysteic acid, t-butylglycine, t-butylalanine, phenylglycine, cyclohexylalanine,  $\beta$ -alanine, fluoro-amino acids, designer amino acids such as  $\beta$ -methyl amino acids, C $\alpha$ -methyl amino acids, N $\alpha$ -methyl amino acids, and amino acid analogs in general. Furthermore, the amino acid can be D (dextrorotary) or L (levorotary).

20 In cases where natural products are suspected of being mutant or are purified from new species, the amino acid sequence of a component protein purified from the natural source, as well as those expressed *in vitro*, or from synthesized expression vectors *in vivo* or *in vitro*, can be determined from analysis of the DNA sequence, or alternatively, by direct sequencing of the purified protein. Such analysis can be performed by manual sequencing or through use of an  
25 automated amino acid sequenator.

The complexes can also be analyzed by hydrophilicity analysis (Hopp and Woods, 1981, Proc. Natl. Acad. Sci. USA 78:3824-3828). A hydrophilicity profile can be used to identify the hydrophobic and hydrophilic regions of the proteins, and help predict their orientation in  
30 designing substrates for experimental manipulation, such as in binding experiments, antibody synthesis, etc. Secondary structural analysis can also be done to identify regions of the component proteins, or their derivatives, that assume specific structures (Chou and Fasman, 1974, Biochemistry 13:222-23). Manipulation, translation, secondary structure prediction, hydrophilicity and hydrophobicity profile predictions, open reading frame prediction and



plotting, and determination of sequence homologies, etc., can be accomplished using computer software programs available in the art.

Other methods of structural analysis including but not limited to X-ray crystallography (Engstrom, 1974 *Biochem. Exp. Biol.* 11:7-13), mass spectroscopy and gas chromatography (Methods in Protein Science, J. Wiley and Sons, New York, 1997), and computer modeling (Fletterick and Zoller, eds., 1986, *Computer Graphics and Molecular Modeling*, In: *Current Communications in Molecular Biology*, Cold Spring Harbor Laboratory, Cold Spring Harbor Press, New York) can also be employed.

In certain embodiments, at least one component of the complex is generated by recombinant DNA technology and is a derivative of the naturally occurring protein. In certain embodiments, the derivative is a fusion protein, wherein the amino acid sequence of the naturally occurring protein is fused to a second amino acid sequence. The second amino acid sequence can be a peptide tag that facilitates the purification, immunological detection and identification as well as visualization of the protein. A variety of peptide tags with different functions and affinities can be used in the invention to facilitate the purification of the component or the complex comprising the component by affinity chromatography. A specific peptide tag comprises the constant regions of an immunoglobulin. In other embodiments, the component is fused to a leader sequence to promote secretion of the protein component from the cell that expresses the protein component. Other peptide tags that can be used with the invention include, but are not limited to, FLAG epitope or polyHistidine tag, *e.g.*, Hisx6 tag.

If the components of the complex are co-expressed, the complex can be purified by any method known to the skilled artisan, including immunoprecipitation, ammonium sulfate precipitation, acid extraction, anion or cation exchange chromatography, phosphocellulose chromatography, immunoaffinity chromatography, hydroxyapatite chromatography, and lectin chromatography.

The methods described herein can be used to purify the individual components of the complex of the invention. The methods can also be used to purify the entire complex. Generally, the purification conditions as well as the dissociation constant of the complex will determine whether the complex remains intact during the purification procedure. Such conditions include, but are not limited to, salt concentration, detergent concentration, pH and redox-potential.

If at least one component of the complex comprises a peptide tag, the invention the invention also contemplates methods for the purification of the complexes of the invention

which are based on the properties of the peptide tag. One approach is based on specific molecular interactions between a tag and its binding partner. The other approach relies on the immunospecific binding of an antibody to an epitope present on the tag. The principle of affinity chromatography well known in the art is generally applicable to both of these approaches. In another embodiment, the complex is purified using immunoprecipitation.

Described in section 4.3.5 below are several methods based on specific molecular interactions of a tag and its binding partner. The embodiments described in section 4.3.5 may be used to recover and purify protein components of the complex separately or to recover and purify the complexes of the invention. Methods that do not require lowering pH or denaturing conditions are most preferred for purification of the complexes.

In certain embodiments, the individual components of a complex of the invention are expressed separately. The components are subsequently incubated under conditions conducive to the binding of the components of the complex to each other to generate the complex. In certain, more specific embodiments, the components are purified before complex-formation. In other embodiments the supernatants of cells that express the component (if the component is secreted) or cell lysates of cells that express the component (if the component is not secreted) are combined first to give rise to the complex, and the complex is purified subsequently. Parameters affecting the ability of the components of the invention to bind to each other include, but are not limited to, salt concentration, detergent concentration, pH, and redox-potential. Once the complex has formed, the complex can be purified or concentrated by any method known to the skilled artisan. In certain embodiments, the complex is separated from the remaining individual components by filtration. The pore size of the filter should be such, that the individual components can still pass through the filter, but the complex does not pass through the filter. Other methods for enriching the complex include sucrose gradient centrifugation and chromatography.

#### **4.3.1 HOMOLOGS, DERIVATIVES AND FRAGMENTS OF THE COMPONENTS**

In certain embodiments, at least one component of a complex of the invention is a homolog, a derivative, *e.g.*, a functionally active derivative, a fragment, *e.g.*, a functionally active fragment, of a protein component of a complex of the invention. In certain embodiments of the invention, a homolog, derivative or fragment of a protein component of a complex of the invention is still capable of forming a complex with the other component(s). Complex-

formation can be tested by any method known to the skilled artisan. Such methods include, but are not limited to, non-denaturing PAGE, FRET, and Fluorescence Polarization Assay.

In certain embodiments, a fragment of a protein component of the complex consists of at least 6 (continuous) amino acids, of at least 10, at least 20 amino acids, at least 30 amino acids, at least 40 amino acids, at least 50 amino acids, at least 75 amino acids, at least 100 amino acids, at least 150 amino acids, at least 200 amino acids, at least 250 amino acids, at least 300 amino acids, at least 400 amino acids, or at least 500 amino acids of the protein component of the naturally occurring proteins. In specific embodiments, such fragments are not larger than 40 amino acids, 50 amino acids, 75 amino acids, 100 amino acids, 150 amino acids, 200 amino acids, 250 amino acids, 300 amino acids, 400 amino acids, or than 500 amino acids. In more specific embodiments, the functional fragment is capable of forming a complex of the invention, *i.e.*, the fragment can still bind to at least one other protein component to form a complex of the invention.

Derivatives or analogs of component proteins include, but are not limited, to molecules comprising regions that are substantially homologous to the component proteins, in various embodiments, by at least 30%, 40%, 50%, 60%, 70%, 80%, 90% or 95% identity over an amino acid sequence of identical size or when compared to an aligned sequence in which the alignment is done by a computer homology program known in the art, or whose encoding nucleic acid is capable of hybridizing to a sequence encoding the component protein under stringent, moderately stringent, or nonstringent conditions.

Derivatives or analogs of component proteins also include, but are not limited, to molecules that (i) comprise regions that are substantially homologous to the component proteins, in various embodiments, by at least 30%, 40%, 50%, 60%, 70%, 80%, 90% or 95% identity over an amino acid sequence of identical size or when compared to an aligned sequence in which the alignment is done by a computer homology program known in the art, or whose encoding nucleic acid is capable of hybridizing to a sequence encoding the component protein under stringent, moderately stringent, or nonstringent conditions; (ii) are capable of forming a complex of the invention. Further, derivatives or analogs of component proteins also include, but are not limited, to molecules that comprise regions that are substantially homologous to the component proteins, in various embodiments, by at least 30%, 40%, 50%, 60%, 70%, 80%, 90% or 95% identity over an amino acid sequence of identical size or when compared to an aligned sequence in which the alignment is done by a computer homology program known in the art, or whose encoding nucleic acid is capable of hybridizing to a sequence encoding the component protein

under stringent, moderately stringent, or nonstringent conditions and wherein a complex that comprises the derivative has RNA-nucleolytic activity (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention).

Derivatives of a protein component include, but are not limited to, fusion proteins of a protein component of a complex of the invention to a heterologous amino acid sequence, mutant forms of a protein component of a complex of the invention, and chemically modified forms of a protein component of a complex of the invention. In a specific embodiment, the functional derivative of a protein component of a complex of the invention is capable of forming a complex of the invention, *i.e.*, the derivative can still bind to at least one other protein component to form a complex of the invention.

Homologs (*e.g.*, nucleic acids encoding component proteins from other species) or other related sequences (*e.g.*, paralogs) which are members of a native cellular protein complex can be identified and obtained by low, moderate or high stringency hybridization with all or a portion of the particular nucleic acid sequence as a probe, using methods well known in the art for nucleic acid hybridization and cloning.

In certain embodiments, a homolog of a first protein binds to the same proteins to which the first protein binds. In certain, more specific embodiments, a homolog of a first protein binds to the same proteins to which the first protein binds wherein the binding affinity between the homolog and the binding partner of the first protein is at least 10%, at least 20%, at least 30%, at least 40%, at least 50%, at least 60%, at least 70%, at least 80%, at least 90%, at least 95% or at least 98% of the binding affinity between the first protein and the binding partner. Binding affinities between proteins can be determined by any method known to the skilled artisan.

It is well-known to the skilled artisan that hybridization conditions, such as, but not limited to, temperature, salt concentration, pH, formamide concentration (see, *e.g.*, Sambrook et al., 1989, Chapters 9 to 11, Molecular Cloning, A Laboratory Manual, 2d Ed., Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York). In certain embodiments, hybridization is performed in aqueous solution and the ionic strength of the solution is kept constant while the hybridization temperature is varied dependent on the degree of sequence homology between the sequences that are to be hybridized. For DNA sequences that 100% identical to each other and are longer than 200 basepairs, hybridization is carried out at approximately 15-25°C below the melting temperature ( $T_m$ ) of the perfect hybrid. The melting

temperature ( $T_m$ ) can be calculated using the following equation (Bolton and McCarthy, Proc. Natl. Acad. Sci. USA 84:1390 (1962)):

$$T_m = 81.5^{\circ}\text{C} - 16.6(\log_{10}[\text{Na}^+]) + (\%G+C) - 0.63(\%\text{formamide}) - (600/l)$$

Wherein ( $T_m$ ) is the melting temperature,  $[\text{Na}^+]$  is the sodium concentration, G+C is the  
5 Guanine and Cytosine content, and  $l$  is the length of the hybrid in basepairs. The effect of mismatches between the sequences can be calculated using the formula by Bonner *et al.* (Bonner *et al.*, 1973, J. Mol. Biol. 81:123-135): for every 1% of mismatching of bases in the hybrid, the melting temperature is reduced by 1-1.5°C.

Thus, by determining the hybridization temperature of the hybrid of two sequences with  
10 a certain percentage of homology to each other and comparing the determined hybridization temperature with the temperature at which the perfect hybrids of the two sequences form allows to estimate the difference in sequence between the two sequences.

By way of example and not limitation, procedures using such conditions of high stringency are as follows. Prehybridization of filters containing DNA is carried out for 8 h to  
15 overnight at 65 C in buffer composed of 6X SSC, 50 mM Tris-HCl (pH 7.5), 1 mM EDTA, 0.02% PVP, 0.02% Ficoll, 0.02% BSA, and 500 µg/ml denatured salmon sperm DNA. Filters are hybridized for 48 h at 65 C in prehybridization mixture containing 100 µg/ml denatured salmon sperm DNA and 5-20 X 10<sup>6</sup> cpm of 32P-labeled probe. Washing of filters is done at 37 C for 1 h in a solution containing 2X SSC, 0.01% PVP, 0.01% Ficoll, and 0.01% BSA. This is  
20 followed by a wash in 0.1X SSC at 50 C for 45 min before autoradiography. Other conditions of high stringency which may be used are well known in the art. Alternatively, another system for high stringency is as follows: hybridization to filter-bound DNA in 0.5 M NaHPO<sub>4</sub>, 7% sodium dodecyl sulfate (SDS), 1 mM EDTA at 65°C, and washing in 0.1xSSC/0.1% SDS at 68°C (Ausubel F.M. et al., eds., 1989, Current Protocols in Molecular Biology, Vol. I, Green  
25 Publishing Associates, Inc., and John Wiley & sons, Inc., New York, at p. 2.10.3). Other conditions of high stringency which may be used are well known in the art.

In other embodiments of the invention, hybridization is performed under moderate or low stringency conditions, such conditions are well-known to the skilled artisan (see e.g.,  
Sambrook et al., 1989, Molecular Cloning, A Laboratory Manual, 2d Ed., Cold Spring Harbor  
30 Laboratory Press, Cold Spring Harbor, New York; see also, Ausubel et al., eds., in the Current Protocols in Molecular Biology series of laboratory technique manuals, 1987-1997 Current Protocols, © 1994-1997 John Wiley and Sons, Inc.). An illustrative low stringency condition is provided by the following system of buffers: hybridization in a buffer comprising 35%

formamide, 5X SSC, 50 mM Tris-HCl (pH 7.5), 5 mM EDTA, 0.02% PVP, 0.02% Ficoll, 0.2% BSA, 100 µg/ml denatured salmon sperm DNA, and 10% (wt/vol) dextran sulfate for 18-20 hours at 40°C, washing in a buffer consisting of 2X SSC, 25 mM Tris-HCl (pH 7.4), 5 mM EDTA, and 0.1% SDS for 1.5 hours at 55°C, and washing in a buffer consisting of 2X SSC, 25 mM Tris-HCl (pH 7.4), 5 mM EDTA, and 0.1% SDS for 1.5 hours at 60°C.

Exemplary moderately stringent hybridization conditions are as follows:  
prehybridization of filters containing DNA is carried out for 8 hours to overnight at 65°C in buffer composed of 6X SSC, 50 mM Tris-HCl (pH 7.5), 1 mM EDTA, 0.02% PVP, 0.02% Ficoll, 0.02% BSA, and 500 µg/ml denatured salmon sperm DNA. Filters are hybridized for 48 hours at 65°C in prehybridization mixture containing 100 µg/ml denatured salmon sperm DNA and 5-20 X 10<sup>6</sup> cpm of <sup>32</sup>P-labeled probe. Washing of filters is done at 37°C for 1 hour in a solution containing 2X SSC, 0.01% PVP, 0.01% Ficoll, and 0.01% BSA. This is followed by a wash in 0.1X SSC at 50°C for 45 min before autoradiography.

#### 4.3.2 INTERSUBUNIT CROSSLINKS

In certain embodiments of the invention, at least two components of a complex of the invention are linked to each other via at least one covalent bond. A covalent bond between components of a complex of the invention increases the stability of the complex of the invention because it prevents the dissociation of the components. Any method known to the skilled artisan can be used to achieve a covalent bond between at least two components of the invention.

In specific embodiments, covalent cross-links are introduced between adjacent subunits. Such cross-links can be between the sidechains of amino acids at opposing sides of the dimer interface. Any functional groups of amino acid residues at the dimer interface in combination with suitable cross-linking agents can be used to create covalent bonds between the protein components at the dimer interface. Existing amino acids at the dimer interface can be used or, alternatively, suitable amino acids can be introduced by site-directed mutagenesis.

In exemplary embodiments, cysteine residues at opposing sides of the dimer interface are oxidized to form disulfide bonds. See, *e.g.*, Reznik *et al.*, 1996, Nature Biotechnology 14:1007-1011, at page 1008. 1,3-dibromoacetone can also be used to create an irreversible covalent bond between two sulfhydryl groups at the dimer interface. In certain other embodiments, lysine residues at the dimer interface are used to create a covalent bond between the protein components of the complex. Crosslinkers that can be used to create covalent bonds between the

epsilon amino groups of lysine residues are, *e.g.*, but are not limited to, bis(sulfosuccinimidyl)suberate; dimethyladipimide-2HDI; disuccinimidyl glutarate; N-hydroxysuccinimidyl 2,3-dibromopropionate.

#### 5            **4.3.3 FUSION COMPLEXES**

In specific embodiments, at least two components of a complex of the invention are expressed as a fusion protein, *i.e.*, fusion complexes. Any recombinant DNA technology known to the skilled artisan can be used to construct the DNA encoding the fusion complex. Care should be taken that the two or more open reading frames are cloned in frame with each other.

10 Any method known to the skilled artisan can be used to express and purify the fusion protein. Exemplary methods are discussed herein. In certain, more specific embodiments, the two components that form the fusion protein are connected to each other via a linker peptide. Thus, the fusion complex is encoded by the ORF for the first component protein, the ORF encoding the linker peptide, and the ORF encoding the second component protein. Without being bound

15 by theory, the linker peptide retains the two components of the complex in close spatial proximity, thus increasing the rate of binding of the two components to each other and thereby stabilizing the complex of the invention.

#### **4.3.4 PEPTIDE TAG AND/OR LEADER PEPTIDE FUSION**

20 The protein components of the complexes of the invention can be fusion proteins comprising a peptide tag. In certain embodiments, a leader peptide may also be fused to a protein component thereby facilitating the transport of the protein component into the endoplasmic reticulum (ER) for secretion.

In various embodiments, such a fusion protein can be made by ligating a gene sequence

25 encoding a protein component of a complex of the invention to the sequence encoding the peptide tag or the leader peptide in the proper reading frame. If genomic sequences are used, care should be taken to ensure that the modified gene remains within the same translational reading frame, uninterrupted by translational stop signals and/or spurious messenger RNA splicing signals.

30 In a specific embodiment, the peptide tag is fused at its amino terminal to the carboxyl terminal of the ORF for the protein component. The precise site at which the fusion is made in the carboxyl terminal is not critical. For example, the peptide tag may replace part of the ORF

encoding the protein component. The optimal site can be determined by routine experimentation.

A variety of peptide tags known in the art may be used to generate fusion proteins of the protein components of a complex of the invention, such as but not limited to the immunoglobulin constant regions, polyhistidine sequence (Petty, 1996, Metal-chelate affinity chromatography, in Current Protocols in Molecular Biology, Vol. 2, Ed. Ausubel et al., Greene Publish. Assoc. & Wiley Interscience), glutathione S-transferase (GST; Smith, 1993, Methods Mol. Cell Bio. 4:220-229), the *E. coli* maltose binding protein (Guan et al., 1987, Gene 67:21-30), and various cellulose binding domains (U.S. patent 5,496,934; 5,202,247; 5,137,819; Tomme et al., 1994, Protein Eng. 7:117-123), etc. Some peptide tags may afford the fusion protein novel structural properties, such as the ability to form multimers. Peptide tags that promote homodimerization or homopolymerization are usually derived from proteins that normally exist as homopolymers. Peptide tags such as the extracellular domains of CD8(Shiue et al., 1988, J. Exp. Med. 168:1993-2005), or CD28 (Lee et al., 1990, J. Immunol. 145:344-352), or portions of the immunoglobulin molecule containing sites for interchain disulfide bonds, could lead to the formation of multimers. In certain embodiments, the formation of homodimers or homomultimers can interfere with the formation of a complex of the invention. If this is the case, peptide tags that do not promote the formation of homodimers or homomultimers should be used.

Other possible peptide tags are short amino acid sequences to which monoclonal antibodies are available, such as but not limited to the following well known examples, the FLAG epitope, the myc epitope at amino acids 408-439, the influenza virus hemagglutinin (HA) epitope. Other peptide tags are recognized by specific binding partners and thus facilitate isolation by affinity binding to the binding partner, which is preferably immobilized and/or on a solid support. As will be appreciated by those skilled in the art, many methods can be used to obtain the coding region of the above-mentioned peptide tags, including but not limited to, DNA cloning, DNA amplification, and synthetic methods. Some of the peptide tags and reagents for their detection and isolation are available commercially.

In certain embodiments, a combination of different peptide tags is used for the purification of the protein components of a complex of the invention or for the purification of a complex. In certain embodiments, at least one component has at least two peptide tags, *e.g.*, a FLAG tag and a His tag. The different tags can be fused together or can be fused in different positions to the protein component. In the purification procedure, the different peptide tags are used subsequently or concurrently for purification. In certain embodiments, at least two



different components are fused to a peptide tag, wherein the peptide tags of the two components can be identical or different. Using different tagged components for the purification of the complex ensures that only complex will be purified and minimizes the amount of uncomplexed protein components, such as monomers or homodimers.

5           A specific peptide tag is a non-variable portion of the immunoglobulin molecule. Typically, such portions comprises at least a functionally CH2 and CH3 domains of the constant region of an immunoglobulin heavy chain. Fusions are also made using the carboxyl terminus of the Fc portion of a constant domain, or a region immediately amino-terminal to the CH1 of the heavy or light chain. Suitable immunoglobulin-based peptide tag may be obtained from  
10 IgG-1, -2, -3, or -4 subtypes, IgA, IgE, IgD, or IgM, but preferably IgG1. Preferably, a human immunoglobulin is used when the protein component is intended for *in vivo* use for humans. DNA sequences encoding immunoglobulin light or heavy chain constant regions are well-known or readily available from cDNA libraries. In a specific embodiment, such DNA sequences can be amplified using PCR. See, for example, Adams et al., Biochemistry, 1980, 19:2711-2719;  
15 Gough et al., 1980, Biochemistry, 19:2702-2710; Dolby et al., 1980, Proc. Natl. Acad. Sci. U.S.A., 77:6027-6031; Rice et al., 1982, Proc. Natl. Acad. Sci. U.S.A., 79:7862-7865; Falkner et al., 1982, Nature, 298:286-288; and Morrison et al., 1984, Ann. Rev. Immunol, 2:239-256. Because many immunological reagents and labeling systems are available for the detection of immunoglobulins, the fusion protein of a protein component of a complex of the invention can  
20 readily be detected and quantified by a variety of immunological techniques known in the art, such as the use of enzyme-linked immunosorbent assay (ELISA), immunoprecipitation, fluorescence activated cell sorting (FACS), etc. Similarly, if the peptide tag is an epitope with readily available antibodies, such reagents can be used with the techniques mentioned above to detect, quantitate, and isolate the fusion protein component of a complex of the invention  
25 containing the peptide tag.

          In a specific embodiment, a protein component is fused to the hinge, CH2 and CH3 domains of murine immunoglobulin G-1 (IgG-1)(Bowen et al., J. Immunol. 156:442-9). This peptide contains three cysteine residues which are normally involved in disulfide bonding with other cysteines in the Ig molecule. Since none of the cysteines are required for the peptide to  
30 function as a tag, one or more of these cysteine residues may optionally be substituted by another amino acid residue, such as for example, serine.

          Various leader sequences known in the art can be used for the efficient secretion of a protein component of a complex of the invention from bacterial and mammalian cells (von Heijne, 1985, J. Mol. Biol. 184:99-105). Leader peptides are selected based on the intended host

cell, and may include bacterial, yeast, viral, animal, and mammalian sequences. For example, the herpes virus glycoprotein D leader peptide is suitable for use in a variety of mammalian cells. A preferred leader peptide for use in mammalian cells can be obtained from the V-J2-C region of the mouse immunoglobulin kappa chain (Bernard et al., 1981, Proc. Natl. Acad. Sci. 5 78:5812-5816).

DNA sequences encoding desired peptide tag or leader peptide which are known or readily available from libraries or commercial suppliers are suitable in the practice of this invention.

#### 4.3.5 PURIFICATION OF COMPLEXES OF THE INVENTION

10 The complexes of the invention can be purified by any method known to the skilled artisan. The methods described for the purification of a complex may also be used to purify individual protein components. In certain embodiments, the complex is formed in the expression system itself, wherein the expression system can be, *e.g.*, a cell or a cell-free expression system (such as a TNT ® Coupled Reticulocyte Lysate System, which is 15 commercially available from Promega Corporation, Madison WI). Once the protein components are expressed and the complex is formed, the complex is purified from the other components of the expression system and the individual protein components by any method known to the skilled artisan. If the expression system is a cell, the cell is lysed once the protein components are expressed and once the complex is formed, the protein complex of the invention is then 20 purified from the lysate. In certain other embodiments, the protein components of a complex of the invention are expressed and purified individually and subsequently the purified components are combined to form the complex. The individual protein components can be purified by any method known to the skilled artisan.

In certain embodiments, the complex is purified via affinity chromatography using 25 antibodies that are specific to the complex. In other embodiments, the complex is purified by performing subsequent purification steps wherein each step requires the presence of a different protein component in the complex to ensure that the purified complex is free of any monomeric protein components. Each individual purification step can be, *e.g.*, based on the peptide tag of a protein component (for a more detailed description of the use of peptide tags in protein 30 purification see below) or an affinity purification using antibodies specific to the protein component. Care should be taken that the antibodies to be used for the purification of the complex are not directed to epitopes that are located at the binding interface of the protein component.

In certain embodiments, a complex of the invention is purified via a protein tag that is fused to at least one of the protein components of the complex. In more specific embodiments, two protein components of a complex are fused to a peptide tag and one protein component is fused to a peptide tag different from the peptide tag to which the other protein component is fused. The complex is first purified via the one and subsequently via the other peptide tag to ensure that the purified complex is free from any monomeric protein components.

A method that is generally applicable to purifying a protein component that is fused to the constant regions of immunoglobulin or a complex that comprises a component that is fused to the constant regions of immunoglobulin is protein A affinity chromatography, a technique that is well known in the art. Staphylococcus protein A is a 42 kD polypeptide that binds specifically to a region located between the second and third constant regions of heavy chain immunoglobulins. Because of the Fc domains of different classes, subclasses and species of immunoglobulins, affinity of protein A for human Fc regions is strong, but may vary with other species. Subclasses that are less preferred include human IgG-3, and most rat subclasses. For certain subclasses, protein G (of Streptococci) may be used in place of protein A in the purification. Protein-A sepharose (Pharmacia or Biorad) is a commonly used solid phase for affinity purification of antibodies, and can be used essentially in the same manner for the purification of a protein component fused to an immunoglobulin Fc fragment. The protein component that is fused to the constant regions of immunoglobulin or a complex that comprises a component that is fused to the constant regions of immunoglobulin binds specifically to protein A on the solid phase, while the contaminants are washed away. Bound protein component that is fused to the constant regions of immunoglobulin or a complex that comprises a component that is fused to the constant regions of immunoglobulin can be eluted by various buffer systems known in the art, including a succession of citrate, acetate and glycine-HCl buffers which gradually lowers the pH. This method is less preferred if the recombinant cells also produce antibodies which will be copurified with the protein component that is fused to the constant regions of immunoglobulin or a complex that comprises a component that is fused to the constant regions of immunoglobulin. See, for example, Langone, 1982, J. Immunol. meth. 51:3; Wilchek et al., 1982, Biochem. Intl. 4:629; Sjobring et al., 1991, J. Biol. Chem. 26:399; page 617-618, in Antibodies A Laboratory Manual, edited by Harlow and Lane, Cold Spring Harbor laboratory, 1988.

Alternatively, a polyhistidine tag may be used, in which case, the protein component that is fused to the polyhistidine tag or a complex that comprises a component that is fused to the polyhistidine tag can be purified by metal chelate chromatography. The polyhistidine tag,

usually a sequence of six histidines, has a high affinity for divalent metal ions, such as nickel ions ( $\text{Ni}^{2+}$ ), which can be immobilized on a solid phase, such as nitrilotriacetic acid-matrices. Polyhistidine has a well characterized affinity for  $\text{Ni}^{2+}$ -NTA-agarose, and can be eluted with either of two mild treatments: imidazole (0.1-0.2 M) will effectively compete with the resin for  
5 binding sites; or lowering the pH just below 6.0 will protonate the histidine sidechains and disrupt the binding. The purification method comprises loading the cell culture supernatant onto the  $\text{Ni}^{2+}$ -NTA-agarose column, washing the contaminants through, and eluting the protein component that is fused to the polyhistidine tag or a complex that comprises a component that is fused to the polyhistidine tag with imidazole or weak acid.  $\text{Ni}^{2+}$ -NTA-agarose can be obtained  
10 from commercial suppliers such as Sigma (St. Louis) and Qiagen. Antibodies that recognize the polyhistidine tag are also available which can be used to detect and quantitate the protein component that is fused to the polyhistidine tag or a complex that comprises a component that is fused to the polyhistidine tag.

Another exemplary peptide tag that can be used is the glutathione-S-transferase (GST)  
15 sequence, originally cloned from the helminth, *Schistosoma japonicum*. In general, a protein component-GST fusion or a complex comprising a protein component-GST fusion expressed in a host cell can be purified from the cell culture supernatant by absorption with glutathione agarose beads, followed by elution in the presence of free reduced glutathione at neutral pH. Denaturing conditions are not required at any stage during purification, and therefore, it may be  
20 desirable for the purification of the complex. Moreover, since GST is known to form dimers under certain conditions, dimeric protein components may be obtained. See, Smith, 1993, Methods Mol. Cell Bio. 4:220-229.

Another useful peptide tag that can be used is the maltose binding protein (MBP) of *E. coli*, which is encoded by the *malE* gene. The protein component-MBP fusion protein or the  
25 complex comprising a component-MPP fusion protein binds to amylose resin while contaminants are washed away. The bound modified protein component-MBP is eluted from the amylose resin by maltose. See, for example, Guan et al., 1987, Gene 67:21-30.

The second approach for purifying protein component fusion proteins is applicable to peptide tags that contain an epitope for which polyclonal or monoclonal antibodies are available.  
30 Various methods known in the art for purification of protein by immunospecific binding, such as immunoaffinity chromatography, and immunoprecipitation, can be used. See, for example, Chapter 13 in Antibodies A Laboratory Manual, edited by Harlow and Lane, Cold Spring Harbor laboratory, 1988; and Chapter 8, Sections I and II, in Current Protocols in Immunology,

ed. by Coligan et al., John Wiley, 1991; the disclosure of which are both incorporated by reference herein.

A protein component of a complex of the invention can also be purified by immunoaffinity chromatography or immunoprecipitation using antibodies that are specific to the component. Likewise, a complex of the invention can be purified by immunoaffinity chromatography or immunoprecipitation using antibodies that bind to at least one of the components of the complex. In a specific embodiment, a complex of the invention can be purified by immunoaffinity chromatography or immunoprecipitation using antibodies that are specific to the complex.

#### 10           4.4 ANTIBODIES OF THE INVENTION

The present invention provides antibodies or fragments thereof that immunospecifically bind to a complex of the invention, to Sen2, to Sen15, to Sen34, to Sen54, or to Sen2deltaEx8.

According to the present invention, a protein complex of the present invention as described in section 4.2 or Sen2, Sen15, Sen34, Sen54, or Sen2deltaEx8 can be used as an immunogen to generate antibodies which immunospecifically bind such immunogen. In certain embodiments, the immunogen is a complex of the invention, wherein the protein components of the complex are covalently linked to each other. In certain embodiments of the invention, the affinity of an antibody that binds to a complex of the invention is higher than the affinity of the antibody to any of the components of the complex individually. In certain embodiments of the invention, the affinity of an antibody that binds to a complex of the invention is at least 2 times, at least 5 times, at least 10 times, at least 100 times, at least 1,000 times, at least 10,000 times or at least 100,000 times higher than the affinity of the antibody to any of the components of the complex individually. In certain embodiments of the invention, the affinity of an antibody that binds to a complex of the invention is at most 2 times, at most 5 times, at most 10 times, at most 100 times, at most 1,000 times, at most 10,000 times or at most 100,000 times higher than the affinity of the antibody to any of the components of the complex individually. In a specific embodiment, the antibody specific to the complex and the antibody does not bind the individual protein components of the complex. The binding affinity of an antibody to an antigen, such as the complex or a protein component, can be determined by any method described herein (*e.g.*, the BIAcore assay) or known to the skilled artisan (see, *e.g.*, van Cott et al., 1992, Real-time biospecific interaction analysis of antibody reactivity to peptides from the envelope glycoprotein, gp160, of HIV-1, J Immunol Methods 146(2):163-76).

According to the present invention, Sen2ΔEx8 as described in section 4.1 can be used as an immunogen to generate antibodies which immunospecifically bind such immunogen.

In a preferred embodiment, an antibody of the invention immuno-specifically binds to Sen2deltaEx8 but not to Sen2. In certain embodiments of the invention, the affinity of an antibody that binds to Sen2deltaEx8 is higher than the affinity of the antibody to Sen2. In certain embodiments of the invention, the affinity of an antibody that binds to Sen2deltaEx8 is at least 2 times, at least 5 times, at least 10 times, at least 100 times, at least 1,000 times, at least 10,000 times or at least 100,000 times higher than the affinity of the antibody to Sen2. In certain embodiments of the invention, the affinity of an antibody that binds to Sen2deltaEx8 is at most 2 times, at most 5 times, at most 10 times, at most 100 times, at most 1,000 times, at most 10,000 times or at most 100,000 times higher than the affinity of the antibody to Sen2. In accordance with these embodiments, the affinity of the antibody may be determined utilizing methods described herein or known in the art (*e.g.*, the BIAcore Assay).

Such antibodies include, but are not limited to, polyclonal, monoclonal, chimeric, single chain, Fab fragments, and an Fab expression library. In a specific embodiment, antibodies to a complex comprising human protein components are produced. In another embodiment, a complex formed from a fragment of said first protein component and a fragment of said second protein component, which fragments contain the protein domain that interacts with the other component of the complex, are used as an immunogen for antibody production.

The antibodies that immunospecifically bind to an antigen can be produced by any method known in the art for the synthesis of antibodies, in particular, by chemical synthesis or preferably, by recombinant expression techniques.

Polyclonal antibodies immunospecific for an antigen can be produced by various procedures well-known in the art. For example, the antigen (*i.e.*, a complex of the invention or a component of a complex of the invention) can be administered to various host animals including, but not limited to, rabbits, mice, rats, etc. to induce the production of sera containing polyclonal antibodies specific for the human antigen. Various adjuvants may be used to increase the immunological response, depending on the host species, and include but are not limited to, Freund's (complete and incomplete), mineral gels such as aluminum hydroxide, surface active substances such as lysolecithin, pluronic polyols, polyanions, peptides, oil emulsions, keyhole limpet hemocyanins, dinitrophenol, and potentially useful human adjuvants such as BCG (bacille Calmette-Guerin) and corynebacterium parvum. Such adjuvants are also well known in the art.

Monoclonal antibodies can be prepared using a wide variety of techniques known in the art including the use of hybridoma, recombinant, and phage display technologies, or a combination thereof. For example, monoclonal antibodies can be produced using hybridoma techniques including those known in the art and taught, for example, in Harlow et al.,  
5 Antibodies: A Laboratory Manual, (Cold Spring Harbor Laboratory Press, 2nd ed. 1988); Hammerling, *et al.*, in: Monoclonal Antibodies and T Cell Hybridomas 563 681 (Elsevier, N.Y., 1981) (said references incorporated by reference in their entireties). The term "monoclonal antibody" as used herein is not limited to antibodies produced through hybridoma technology. The term "monoclonal antibody" refers to an antibody that is derived from a single clone,  
10 including any eukaryotic, prokaryotic, or phage clone, and not the method by which it is produced.

Methods for producing and screening for specific antibodies using hybridoma technology are routine and well known in the art. Briefly, mice can be immunized with a non-murine antigen and once an immune response is detected, *e.g.*, antibodies specific for the  
15 antigen are detected in the mouse serum, the mouse spleen is harvested and splenocytes isolated. The splenocytes are then fused by well known techniques to any suitable myeloma cells, for example cells from cell line SP20 available from the ATCC. Hybridomas are selected and cloned by limited dilution. The hybridoma clones are then assayed by methods known in the art for cells that secrete antibodies capable of binding a polypeptide of the invention. Ascites fluid,  
20 which generally contains high levels of antibodies, can be generated by immunizing mice with positive hybridoma clones.

The present invention provides methods of generating monoclonal antibodies as well as antibodies produced by the method comprising culturing a hybridoma cell secreting an antibody of the invention wherein, preferably, the hybridoma is generated by fusing splenocytes isolated  
25 from a mouse immunized with a non-murine antigen with myeloma cells and then screening the hybridomas resulting from the fusion for hybridoma clones that secrete an antibody able to bind to the antigen.

Antibody fragments which recognize specific particular epitopes may be generated by any technique known to those of skill in the art. For example, Fab and F(ab')<sub>2</sub> fragments of the  
30 invention may be produced by proteolytic cleavage of immunoglobulin molecules, using enzymes such as papain (to produce Fab fragments) or pepsin (to produce F(ab')<sub>2</sub> fragments). F(ab')<sub>2</sub> fragments contain the variable region, the light chain constant region and the CH1 domain of the heavy chain. Further, the antibodies of the present invention can also be generated using various phage display methods known in the art.

In phage display methods, functional antibody domains are displayed on the surface of phage particles which carry the polynucleotide sequences encoding them. In particular, DNA sequences encoding VH and VL domains are amplified from animal cDNA libraries (*e.g.*, human or murine cDNA libraries of affected tissues). The DNA encoding the VH and VL domains are recombined together with an scFv linker by PCR and cloned into a phagemid vector. The vector is electroporated in *E. coli* and the *E. coli* is infected with helper phage. Phage used in these methods are typically filamentous phage including fd and M13 and the VH and VL domains are usually recombinantly fused to either the phage gene III or gene VIII. Phage expressing an antigen binding domain that binds to a particular antigen can be selected or identified with antigen, *e.g.*, using labeled antigen or antigen bound or captured to a solid surface or bead. Examples of phage display methods that can be used to make the antibodies of the present invention include those disclosed in Brinkman *et al.*, 1995, J. Immunol. Methods 182:41-50; Ames *et al.*, 1995, J. Immunol. Methods 184:177-186; Kettleborough *et al.*, 1994, Eur. J. Immunol. 24:952-958; Persic *et al.*, 1997, Gene 187:9-18; Burton *et al.*, 1994, Advances in Immunology 57:191-280; International application No. PCT/GB91/O1 134; International publication Nos. WO 90/02809, WO 91/10737, WO 92/01047, WO 92/18619, WO 93/11236, WO 95/15982, WO 95/20401, and WO97/13844; and U.S. Patent Nos. 5,698,426, 5,223,409, 5,403,484, 5,580,717, 5,427,908, 5,750,753, 5,821,047, 5,571,698, 5,427,908, 5,516,637, 5,780,225, 5,658,727, 5,733,743 and 5,969,108; each of which is incorporated herein by reference in its entirety.

As described in the above references, after phage selection, the antibody coding regions from the phage can be isolated and used to generate whole antibodies, including human antibodies, or any other desired antigen binding fragment, and expressed in any desired host, including mammalian cells, insect cells, plant cells, yeast, and bacteria, *e.g.*, as described below. Techniques to recombinantly produce Fab, Fab' and F(ab')<sub>2</sub> fragments can also be employed using methods known in the art such as those disclosed in PCT publication No. WO 92/22324; Mullinax *et al.*, 1992, BioTechniques 12(6):864-869; Sawai *et al.*, 1995, AJRI 34:26-34; and Better *et al.*, 1988, Science 240:1041-1043 (said references incorporated by reference in their entireties).

To generate whole antibodies, PCR primers including VH or VL nucleotide sequences, a restriction site, and a flanking sequence to protect the restriction site can be used to amplify the VH or VL sequences in scFv clones. Utilizing cloning techniques known to those of skill in the art, the PCR amplified VH domains can be cloned into vectors expressing a VH constant region, *e.g.*, the human gamma 4 constant region, and the PCR amplified VL domains can be cloned



into vectors expressing a VL constant region, *e.g.*, human kappa or lambda constant regions. Preferably, the vectors for expressing the VH or VL domains comprise an EF-1 $\alpha$  promoter, a secretion signal, a cloning site for the variable domain, constant domains, and a selection marker such as neomycin. The VH and VL domains may also be cloned into one vector expressing the  
5 necessary constant regions. The heavy chain conversion vectors and light chain conversion vectors are then co-transfected into cell lines to generate stable or transient cell lines that express full-length antibodies, *e.g.*, IgG, using techniques known to those of skill in the art.

For some uses, including *in vivo* use of antibodies in humans and *in vitro* detection assays, it may be preferable to use humanized antibodies or chimeric antibodies. Completely  
10 human antibodies and humanized antibodies are particularly desirable for therapeutic treatment of human subjects. Human antibodies can be made by a variety of methods known in the art including phage display methods described above using antibody libraries derived from human immunoglobulin sequences. See also U.S. Patent Nos. 4,444,887 and 4,716,111; and International publication Nos. WO 98/46645, WO 98/50433, WO 98/24893, WO98/16654, WO  
15 96/34096, WO 96/33735, and WO 91/10741; each of which is incorporated herein by reference in its entirety.

Human antibodies can also be produced using transgenic mice which are incapable of expressing functional endogenous immunoglobulins, but which can express human immunoglobulin genes. For example, the human heavy and light chain immunoglobulin gene  
20 complexes may be introduced randomly or by homologous recombination into mouse embryonic stem cells. Alternatively, the human variable region, constant region, and diversity region may be introduced into mouse embryonic stem cells in addition to the human heavy and light chain genes. The mouse heavy and light chain immunoglobulin genes may be rendered non functional separately or simultaneously with the introduction of human immunoglobulin loci by  
25 homologous recombination. In particular, homozygous deletion of the JH region prevents endogenous antibody production. The modified embryonic stem cells are expanded and microinjected into blastocysts to produce chimeric mice. The chimeric mice are then bred to produce homozygous offspring which express human antibodies. The transgenic mice are immunized in the normal fashion with a selected antigen, *e.g.*, all or a portion of a polypeptide  
30 of the invention. Monoclonal antibodies directed against the antigen can be obtained from the immunized, transgenic mice using conventional hybridoma technology. The human immunoglobulin transgenes harbored by the transgenic mice rearrange during B cell differentiation, and subsequently undergo class switching and somatic mutation. Thus, using such a technique, it is possible to produce therapeutically useful IgG, IgA, IgM and IgE

antibodies. For an overview of this technology for producing human antibodies, see Lonberg and Huszar, 1995, *Int. Rev. Immunol.* 13:65-93. For a detailed discussion of this technology for producing human antibodies and human monoclonal antibodies and protocols for producing such antibodies, see, *e.g.*, International publication Nos. WO 98/24893, WO 96/34096, and WO 96/33735; and U.S. Patent Nos. 5,413,923, 5,625,126, 5,633,425, 5,569,825, 5,661,016, 5,545,806, 5,814,318, and 5,939,598, which are incorporated by reference herein in their entirety. In addition, companies such as Abgenix, Inc. (Freemont, CA) and Genpharm (San Jose, CA) can be engaged to provide human antibodies directed against a selected antigen using technology similar to that described above.

10 A chimeric antibody is a molecule in which different portions of the antibody are derived from different immunoglobulin molecules. Methods for producing chimeric antibodies are known in the art. See *e.g.*, Morrison, 1985, *Science* 229:1202; Oi *et al.*, 1986, *BioTechniques* 4:214; Gillies *et al.*, 1989, *J. Immunol. Methods* 125:191-202; and U.S. Patent Nos. 5,807,715, 4,816,567, 4,816,397, and 6,311,415, which are incorporated herein by reference in their  
15 entirety.

A humanized antibody is an antibody or its variant or fragment thereof which is capable of binding to a predetermined antigen and which comprises a framework region having substantially the amino acid sequence of a human immunoglobulin and a CDR having substantially the amino acid sequence of a non-human immunoglobulin. A humanized antibody  
20 comprises substantially all of at least one, and typically two, variable domains (Fab, Fab', F(ab')<sub>2</sub>, Fabc, Fv) in which all or substantially all of the CDR regions correspond to those of a non human immunoglobulin (*i.e.*, donor antibody) and all or substantially all of the framework regions are those of a human immunoglobulin consensus sequence. Preferably, a humanized antibody also comprises at least a portion of an immunoglobulin constant region  
25 (Fc), typically that of a human immunoglobulin. Ordinarily, the antibody will contain both the light chain as well as at least the variable domain of a heavy chain. The antibody also may include the CH1, hinge, CH2, CH3, and CH4 regions of the heavy chain. The humanized antibody can be selected from any class of immunoglobulins, including IgM, IgG, IgD, IgA and IgE, and any isotype, including IgG1, IgG2, IgG3 and IgG4. Usually the constant domain is a  
30 complement fixing constant domain where it is desired that the humanized antibody exhibit cytotoxic activity, and the class is typically IgG1. Where such cytotoxic activity is not desirable, the constant domain may be of the IgG2 class. The humanized antibody may comprise sequences from more than one class or isotype, and selecting particular constant domains to optimize desired effector functions is within the ordinary skill in the art. The

framework and CDR regions of a humanized antibody need not correspond precisely to the parental sequences, *e.g.*, the donor CDR or the consensus framework may be mutagenized by substitution, insertion or deletion of at least one residue so that the CDR or framework residue at that site does not correspond to either the consensus or the import antibody. Such mutations, however, will not be extensive. Usually, at least 75% of the humanized antibody residues will correspond to those of the parental framework and CDR sequences, more often 90%, and most preferably greater than 95%. A humanized antibody can be produced using variety of techniques known in the art, including but not limited to, CDR-grafting (see *e.g.*, European Patent No. EP 239,400; International Publication No. WO 91/09967; and U.S. Patent Nos. 5,225,539, 5,530,101, and 5,585,089, each of which is incorporated herein in its entirety by reference), veneering or resurfacing (see *e.g.*, European Patent Nos. EP 592,106 and EP 519,596; Padlan, 1991, *Molecular Immunology* 28(4/5):489-498; Studnicka *et al.*, 1994, *Protein Engineering* 7(6):805-814; and Roguska *et al.*, 1994, *PNAS* 91:969-973, each of which is incorporated herein by its entirety by reference), chain shuffling (see *e.g.*, U.S. Patent No. 5,565,332, which is incorporated herein in its entirety by reference), and techniques disclosed in, *e.g.*, U.S. Pat. No. 6,407,213, U.S. Pat. No. 5,766,886, International Publication No. WO 9317105, Tan *et al.*, *J. Immunol.* 169:1119-1125 (2002), Caldas *et al.*, *Protein Eng.* 13(5):353-360 (2000), Morea *et al.*, *Methods* 20(3):267-279 (2000), Baca *et al.*, *J. Biol. Chem.* 272(16):10678-10684 (1997), Roguska *et al.*, *Protein Eng.* 9(10):895-904 (1996), Couto *et al.*, *Cancer Res.* 55 (23 Supp):5973s-5977s (1995), Couto *et al.*, *Cancer Res.* 55(8):1717-1722 (1995), Sandhu JS, *Gene* 150(2):409-410 (1994), and Pedersen *et al.*, *J. Mol. Biol.* 235(3):959-973 (1994), each of which is incorporated herein in its entirety by reference. Often, framework residues in the framework regions will be substituted with the corresponding residue from the CDR donor antibody to alter, preferably improve, antigen binding. These framework substitutions are identified by methods well known in the art, *e.g.* by modeling of the interactions of the CDR and framework residues to identify framework residues important for antigen binding and sequence comparison to identify unusual framework residues at particular positions. (See, *e.g.*, Queen *et al.*, U.S. Patent No. 5,585,089; and Riechmann *et al.*, 1988, *Nature* 332:323, which are incorporated herein by reference in their entireties.)

Further, the antibodies that immunospecifically bind to a complex of the invention or a component of a complex of the invention, in turn, be utilized to generate anti-idiotypic antibodies that "mimic" an antigen using techniques well known to those skilled in the art. (See, *e.g.*, Greenspan & Bona, 1989, *FASEB J.* 7(5):437-444; and Nissinoff, 1991, *J. Immunol.* 147(8):2429-2438).

#### 4.4.1 Polynucleotide Sequences Encoding an Antibody

The invention provides polynucleotides comprising a nucleotide sequence encoding an antibody or fragment thereof that immunospecifically binds to a complex of the invention or a component of a complex of the invention. The invention also encompasses polynucleotides that  
5 hybridize under high stringency, intermediate or lower stringency hybridization conditions, *e.g.*, as defined supra, to polynucleotides that encode an antibody of the invention.

The polynucleotides may be obtained, and the nucleotide sequence of the polynucleotides determined, by any method known in the art. The nucleotide sequence of antibodies immunospecific for a desired antigen can be obtained, *e.g.*, from the literature or a  
10 database such as GenBank. Such a polynucleotide encoding the antibody may be assembled from chemically synthesized oligonucleotides (*e.g.*, as described in Kutmeier *et al.*, 1994, *BioTechniques* 17:242), which, briefly, involves the synthesis of overlapping oligonucleotides containing portions of the sequence encoding the antibody, annealing and ligating of those  
15 oligonucleotides, and then amplification of the ligated oligonucleotides by PCR.

Alternatively, a polynucleotide encoding an antibody may be generated from nucleic acid from a suitable source. If a clone containing a nucleic acid encoding a particular antibody is not available, but the sequence of the antibody molecule is known, a nucleic acid encoding the immunoglobulin may be chemically synthesized or obtained from a suitable source (*e.g.*, an  
20 antibody cDNA library, or a cDNA library generated from, or nucleic acid, preferably poly A+ RNA, isolated from, any tissue or cells expressing the antibody, such as hybridoma cells selected to express an antibody of the invention) by PCR amplification using synthetic primers hybridizable to the 3' and 5' ends of the sequence or by cloning using an oligonucleotide probe specific for the particular gene sequence to identify, *e.g.*, a cDNA clone from a cDNA library  
25 that encodes the antibody. Amplified nucleic acids generated by PCR may then be cloned into replicable cloning vectors using any method well known in the art.

Once the nucleotide sequence of the antibody is determined, the nucleotide sequence of the antibody may be manipulated using methods well known in the art for the manipulation of nucleotide sequences, *e.g.*, recombinant DNA techniques, site directed mutagenesis, PCR, etc.  
30 (see, for example, the techniques described in Sambrook *et al.*, 1990, *Molecular Cloning, A Laboratory Manual*, 2d Ed., Cold Spring Harbor Laboratory, Cold Spring Harbor, NY and Ausubel *et al.*, eds., 1998, *Current Protocols in Molecular Biology*, John Wiley & Sons, NY, which are both incorporated by reference herein in their entireties), to generate antibodies

having a different amino acid sequence, for example to create amino acid substitutions, deletions, and/or insertions.

In a specific embodiment, one or more of the CDRs is inserted within framework regions using routine recombinant DNA techniques. The framework regions may be naturally occurring or consensus framework regions, and preferably human framework regions (see, *e.g.*, Chothia *et al.*, 1998, J. Mol. Biol. 278: 457-479 for a listing of human framework regions). Preferably, the polynucleotide generated by the combination of the framework regions and CDRs encodes an antibody that immunospecifically binds to a particular antigen. Preferably, as discussed supra, one or more amino acid substitutions may be made within the framework regions, and, preferably, the amino acid substitutions improve binding of the antibody to its antigen. Additionally, such methods may be used to make amino acid substitutions or deletions of one or more variable region cysteine residues participating in an intrachain disulfide bond to generate antibody molecules lacking one or more intrachain disulfide bonds. Other alterations to the polynucleotide are encompassed by the present invention and within the skill of the art.

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#### **4.4.2 Recombinant Expression of an Antibody**

Recombinant expression of an antibody of the invention, derivative, analog or fragment thereof, (*e.g.*, a heavy or light chain of an antibody of the invention or a portion thereof or a single chain antibody of the invention), requires construction of an expression vector containing a polynucleotide that encodes the antibody. Once a polynucleotide encoding an antibody molecule or a heavy or light chain of an antibody, or portion thereof (preferably, but not necessarily, containing the heavy or light chain variable domain), of the invention has been obtained, the vector for the production of the antibody molecule may be produced by recombinant DNA technology using techniques well-known in the art. See, *e.g.*, U.S. Patent No. 6,331,415, which is incorporated herein by reference in its entirety. Thus, methods for preparing a protein by expressing a polynucleotide containing an antibody encoding nucleotide sequence are described herein. Methods which are well known to those skilled in the art can be used to construct expression vectors containing antibody coding sequences and appropriate transcriptional and translational control signals. These methods include, for example, *in vitro* recombinant DNA techniques, synthetic techniques, and *in vivo* genetic recombination. The invention, thus, provides replicable vectors comprising a nucleotide sequence encoding an antibody molecule of the invention, a heavy or light chain of an antibody, a heavy or light chain variable domain of an antibody or a portion thereof, or a heavy or light chain CDR, operably



linked to a promoter. Such vectors may include the nucleotide sequence encoding the constant region of the antibody molecule (see, *e.g.*, International Publication No. WO 86/05807 and WO 89/01036; and U.S. Patent No. 5,122,464) and the variable domain of the antibody may be cloned into such a vector for expression of the entire heavy, the entire light chain, or both the entire heavy and light chains.

The expression vector is transferred to a host cell by conventional techniques and the transfected cells are then cultured by conventional techniques to produce an antibody of the invention. Thus, the invention includes host cells containing a polynucleotide encoding an antibody of the invention or fragments thereof, or a heavy or light chain thereof, or portion thereof, or a single chain antibody of the invention, operably linked to a heterologous promoter. In preferred embodiments for the expression of double-chained antibodies, vectors encoding both the heavy and light chains may be co-expressed in the host cell for expression of the entire immunoglobulin molecule, as detailed below.

A variety of host-expression vector systems may be utilized to express the antibody molecules of the invention (see, *e.g.*, U.S. Patent No. 5,807,715). Such host-expression systems represent vehicles by which the coding sequences of interest may be produced and subsequently purified, but also represent cells which may, when transformed or transfected with the appropriate nucleotide coding sequences, express an antibody molecule of the invention in situ. These include but are not limited to microorganisms such as bacteria (*e.g.*, *E. coli* and *B. subtilis*) transformed with recombinant bacteriophage DNA, plasmid DNA or cosmid DNA expression vectors containing antibody coding sequences; yeast (*e.g.*, *Saccharomyces Pichia*) transformed with recombinant yeast expression vectors containing antibody coding sequences; insect cell systems infected with recombinant virus expression vectors (*e.g.*, baculovirus) containing antibody coding sequences; plant cell systems infected with recombinant virus expression vectors (*e.g.*, cauliflower mosaic virus, CaMV; tobacco mosaic virus, TMV) or transformed with recombinant plasmid expression vectors (*e.g.*, Ti plasmid) containing antibody coding sequences; or mammalian cell systems (*e.g.*, COS, CHO, BHK, 293, NS0, and 3T3 cells) harboring recombinant expression constructs containing promoters derived from the genome of mammalian cells (*e.g.*, metallothionein promoter) or from mammalian viruses (*e.g.*, the adenovirus late promoter; the vaccinia virus 7.5K promoter). Preferably, bacterial cells such as *Escherichia coli*, and more preferably, eukaryotic cells, especially for the expression of whole recombinant antibody molecule, are used for the expression of a recombinant antibody molecule. For example, mammalian cells such as Chinese hamster ovary cells (CHO), in conjunction with a vector such as the major intermediate early gene promoter element from

human cytomegalovirus is an effective expression system for antibodies (Foecking *et al.*, 1986, Gene 45:101; and Cockett *et al.*, 1990, Bio/Technology 8:2).

In bacterial systems, a number of expression vectors may be advantageously selected depending upon the use intended for the antibody molecule being expressed. For example, when a large quantity of such an antibody is to be produced, for the generation of pharmaceutical compositions of an antibody molecule, vectors which direct the expression of high levels of fusion protein products that are readily purified may be desirable. Such vectors include, but are not limited to, the *E. coli* expression vector pUR278 (Ruther *et al.*, 1983, EMBO 12:1791), in which the antibody coding sequence may be ligated individually into the vector in frame with the lac Z coding region so that a fusion protein is produced; pIN vectors (Inouye & Inouye, 1985, Nucleic Acids Res. 13:3101-3109; Van Heeke & Schuster, 1989, J. Biol. Chem. 24:5503-5509); and the like. pGEX vectors may also be used to express foreign polypeptides as fusion proteins with glutathione S-transferase (GST). In general, such fusion proteins are soluble and can easily be purified from lysed cells by adsorption and binding to matrix glutathione agarose beads followed by elution in the presence of free glutathione. The pGEX vectors are designed to include thrombin or factor Xa protease cleavage sites so that the cloned target gene product can be released from the GST moiety.

In an insect system, Autographa californica nuclear polyhedrosis virus (AcNPV) is used as a vector to express foreign genes. The virus grows in *Spodoptera frugiperda* cells. The antibody coding sequence may be cloned individually into non-essential regions (for example the polyhedrin gene) of the virus and placed under control of an AcNPV promoter (for example the polyhedrin promoter).

In mammalian host cells, a number of viral-based expression systems may be utilized. In cases where an adenovirus is used as an expression vector, the antibody coding sequence of interest may be ligated to an adenovirus transcription/translation control complex, e.g., the late promoter and tripartite leader sequence. This chimeric gene may then be inserted in the adenovirus genome by *in vitro* or *in vivo* recombination. Insertion in a non-essential region of the viral genome (e.g., region EI or E3) will result in a recombinant virus that is viable and capable of expressing the antibody molecule in infected hosts (e.g., see Logan & Shenk, 1984, Proc. Natl. Acad. Sci. USA 81:355-359). Specific initiation signals may also be required for efficient translation of inserted antibody coding sequences. These signals include the ATG initiation codon and adjacent sequences. Furthermore, the initiation codon must be in phase with the reading frame of the desired coding sequence to ensure translation of the entire insert. These exogenous translational control signals and initiation codons can be of a variety of

origins, both natural and synthetic. The efficiency of expression may be enhanced by the inclusion of appropriate transcription enhancer elements, transcription terminators, etc. (see, *e.g.*, Bittner *et al.*, 1987, *Methods in Enzymol.* 153:51-544).

In addition, a host cell strain may be chosen which modulates the expression of the inserted sequences, or modifies and processes the gene product in the specific fashion desired. Such modifications (*e.g.*, glycosylation) and processing (*e.g.*, cleavage) of protein products may be important for the function of the protein. Different host cells have characteristic and specific mechanisms for the post-translational processing and modification of proteins and gene products. Appropriate cell lines or host systems can be chosen to ensure the correct modification and processing of the foreign protein expressed. To this end, eukaryotic host cells which possess the cellular machinery for proper processing of the primary transcript, glycosylation, and phosphorylation of the gene product may be used. Such mammalian host cells include but are not limited to CHO, VERY, BHK, HeLa, COS, MDCK, 293, 3T3, W138, BT483, Hs578T, HTB2, BT2O and T47D, NS0 (a murine myeloma cell line that does not endogenously produce any immunoglobulin chains), CRL703O and HsS78Bst cells.

For long-term, high-yield production of recombinant proteins, stable expression is preferred. For example, cell lines which stably express the antibody molecule may be engineered. Rather than using expression vectors which contain viral origins of replication, host cells can be transformed with DNA controlled by appropriate expression control elements (*e.g.*, promoter, enhancer, sequences, transcription terminators, polyadenylation sites, etc.), and a selectable marker. Following the introduction of the foreign DNA, engineered cells may be allowed to grow for 1-2 days in an enriched media, and then are switched to a selective media. The selectable marker in the recombinant plasmid confers resistance to the selection and allows cells to stably integrate the plasmid into their chromosomes and grow to form foci which in turn can be cloned and expanded into cell lines. This method may advantageously be used to engineer cell lines which express the antibody molecule. Such engineered cell lines may be particularly useful in screening and evaluation of compositions that interact directly or indirectly with the antibody molecule.

A number of selection systems may be used, including but not limited to, the herpes simplex virus thymidine kinase (Wigler *et al.*, 1977, *Cell* 11:223), hypoxanthineguanine phosphoribosyltransferase (Szybalska & Szybalski, 1992, *Proc. Natl. Acad. Sci. USA* 48:202), and adenine phosphoribosyltransferase (Lowy *et al.*, 1980, *Cell* 22:8-17) genes can be employed in tk-, hgp<sup>r</sup>t- or ap<sup>r</sup>t- cells, respectively. Also, antimetabolite resistance can be used as the basis of selection for the following genes: dhfr, which confers resistance to methotrexate (Wigler *et*



*al.*, 1980, Natl. Acad. Sci. USA 77:357; O'Hare *et al.*, 1981, Proc. Natl. Acad. Sci. USA 78:1527); gpt, which confers resistance to mycophenolic acid (Mulligan & Berg, 1981, Proc. Natl. Acad. Sci. USA 78:2072); neo, which confers resistance to the aminoglycoside G-418 (Wu and Wu, 1991, Biotherapy 3:87-95; Tolstoshev, 1993, Ann. Rev. Pharmacol. Toxicol. 32:573-596; Mulligan, 1993, Science 260:926-932; and Morgan and Anderson, 1993, Ann. Rev. Biochem. 62: 191-217; May, 1993, TIB TECH 11(5):155-2 15); and hygromycin (Santerre *et al.*, 1984, Gene 30:147). Methods commonly known in the art of recombinant DNA technology may be routinely applied to select the desired recombinant clone, and such methods are described, for example, in Ausubel *et al.*, (eds.), Current Protocols in Molecular Biology, John Wiley & Sons, NY (1993); Kriegler, Gene Transfer and Expression, A Laboratory Manual, Stockton Press, NY (1990); and in Chapters 12 and 13, Dracopoli *et al.*, (eds), Current Protocols in Human Genetics, John Wiley & Sons, NY (1994); Colberre-Garapin *et al.*, 1981, J. Mol. Biol. 150:1, which are incorporated by reference herein in their entireties.

15           The expression levels of an antibody molecule can be increased by vector amplification (for a review, see Bebbington and Hentschel, The use of vectors based on gene amplification for the expression of cloned genes in mammalian cells in DNA cloning, Vol.3. (Academic Press, New York, 1987)). When a marker in the vector system expressing antibody is amplifiable, increase in the level of inhibitor present in culture of host cell will increase the number of copies of the marker gene. Since the amplified region is associated with the antibody gene, production of the antibody will also increase (Crouse *et al.*, 1983, Mol. Cell. Biol. 3:257).

20           The host cell may be co-transfected with two expression vectors of the invention, the first vector encoding a heavy chain derived polypeptide and the second vector encoding a light chain derived polypeptide. The two vectors may contain identical selectable markers which enable equal expression of heavy and light chain polypeptides. Alternatively, a single vector may be used which encodes, and is capable of expressing, both heavy and light chain polypeptides. In such situations, the light chain should be placed before the heavy chain to avoid an excess of toxic free heavy chain (Proudfoot, 1986, Nature 322:52; and Kohler, 1980, Proc. Natl. Acad. Sci. USA 77:2 197). The coding sequences for the heavy and light chains may 30           comprise cDNA or genomic DNA.

          Once an antibody molecule of the invention has been produced by recombinant expression, it may be purified by any method known in the art for purification of an immunoglobulin molecule, for example, by chromatography (*e.g.*, ion exchange, affinity, particularly by affinity for the specific antigen after Protein A, and sizing column

chromatography), centrifugation, differential solubility, or by any other standard technique for the purification of proteins. Further, the antibodies of the present invention or fragments thereof may be fused to heterologous polypeptide sequences described herein or otherwise known in the art to facilitate purification.

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#### **4.4.3 Immunological Methods Using the Antibodies of the Invention**

The antibodies of the invention can be used with any method known to the skilled artisan. In certain embodiments, an antibody of the invention is used to detect or quantify a complex of the invention or a component of a complex of the invention. To this end, Western blot analyses, radioimmunoassays, ELISA (enzyme linked immunosorbent assay), “sandwich” immunoassays, immunoprecipitation assays, precipitin reactions, gel diffusion precipitin reactions, immunodiffusion assays, agglutination assays, complement-fixation assays, immunoradiometric assays, or fluorescent immunoassays can be performed using an antibody of the invention.

15       The affinity of an antibody to its antigen can be measured by using, *e.g.*, a Biacore® assay.

#### **4.5 Screening Methods**

##### **4.5.1 Modulators of Complex Formation**

20       A complex of the present invention, the component proteins of the complex and nucleic acids encoding the component proteins, as well as derivatives and fragments of the amino and nucleic acids, can be used to screen for compounds that bind to, or modulate the amount of, activity of, or protein component composition of, said complex, and thus, have potential use as modulators, *i.e.*, agonists or antagonists, of complex activity, and/or complex formation, *i.e.*, the amount of complex formed, and/or protein component composition of the complex.

25       Thus, the present invention is also directed to methods for screening for molecules that bind to, or modulate the amount of, activity of, or protein component composition of, a complex of the present invention. In one embodiment of the invention, the method for screening for a molecule that modulates directly or indirectly the function, activity or formation of a complex of the present invention comprises exposing said complex, or a cell or organism containing the complex machinery, to one or more compounds under conditions conducive to modulation; and determining the amount of, activity of, or identities of the protein components of said complex, wherein a change in said amount, activity, or identities relative to said amount, activity or

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identities in the absence of said compounds indicates that the compounds modulate function, activity or formation of said complex. Such screening assays can be carried out using cell-free and cell-based methods that are commonly known in the art.

The present invention is further directed to methods for screening for molecules that modulate the expression of a component of a complex of the present invention, such as, *e.g.*, Sen2deltaEx8. In one embodiment of the invention, the method for screening for a molecule that modulates the expression of a component of a complex of the invention comprises exposing a cell or organism containing the nucleic acid encoding the component, to one or more compounds under conditions conducive to modulation; and determining the amount of, activity of, or identities of the protein components of said complex, wherein a change in said amount, activity, or identities relative to said amount, activity or identities in the absence of said compounds indicates that the compounds modulate expression of said complex. Such screening assays can be carried out using cell-free and cell-based methods that are commonly known in the art. If activity of the complex or component is used as read-out of the assay, subsequent assays, such as Western blot analysis or Northern blot analysis, may be performed to verify that the modulated expression levels of the component are responsible for the modulated activity.

Screening the libraries can be accomplished by any of a variety of commonly known methods. See, *e.g.*, the following references, which disclose screening of peptide libraries: Parmley and Smith, 1989, *Adv. Exp. Med. Biol.* 251:215-218; Scott and Smith, 1990, *Science* 249:386-390; Fowlkes et al., 1992, *BioTechniques* 13:422-427; Oldenburg et al., 1992, *Proc. Natl. Acad. Sci. USA* 89:5393-5397; Yu et al., 1994, *Cell* 76:933-945; Staudt et al., 1988, *Science* 241:577-580; Bock et al., 1992, *Nature* 355:564-566; Tuerk et al., 1992, *Proc. Natl. Acad. Sci. USA* 89:6988-6992; Ellington et al., 1992, *Nature* 355:850-852; U.S. Patent No. 5,096,815, U.S. Patent No. 5,223,409, and U.S. Patent No. 5,198,346, all to Ladner et al.; Rebar and Pabo, 1993, *Science* 263:671-673; and International Patent Publication No. WO 94/18318.

In a specific embodiment, fragments and/or analogs of protein components of a complex, especially peptidomimetics, are screened for activity as competitive or non-competitive inhibitors of complex formation, which thereby inhibit complex activity or formation.

Methods for screening may involve labeling the component proteins of the complex with radioligands (*e.g.*,  $^{125}\text{I}$  or  $^3\text{H}$ ), magnetic ligands (*e.g.*, paramagnetic beads covalently attached to photobiotin acetate), fluorescent ligands (*e.g.*, fluorescein or rhodamine), or enzyme ligands (*e.g.*, luciferase or beta-galactosidase). The reactants that bind in solution can then be isolated by one of many techniques known in the art, including but not restricted to, co-immunoprecipitation of the labeled complex moiety using antisera against the unlabeled binding

partner (or labeled binding partner with a distinguishable marker from that used on the second labeled complex moiety), immunoaffinity chromatography, size exclusion chromatography, and gradient density centrifugation. In a preferred embodiment, the labeled binding partner is a small fragment or peptidomimetic that is not retained by a commercially available filter. Upon binding, the labeled species is then unable to pass through the filter, providing for a simple assay of complex formation.

In certain embodiments, the protein components of a complex of the invention are labeled with different fluorophores such that binding of the components to each other results in FRET (Fluorescence Resonance Energy Transfer). If the addition of a compound results in a difference in FRET compared to FRET in the absence of the compound, the compound is identified as a modulator of complex formation. If FRET in the presence of the compound is decreased in comparison to FRET in the absence of the compound, the compound is identified as an inhibitor of complex formation. If FRET in the presence of the compound is increased in comparison to FRET in the absence of the compound, the compound is identified as an activator of complex formation.

In certain other embodiments, a protein component of a complex of the invention is labeled with a fluorophore such that binding of the component to another protein component to form a complex of the invention results in FP (Flourescence Polarization). If the addition of a compound results in a difference in FP compared to FP in the absence of the compound, the compound is identified as a modulator of complex formation.

Methods commonly known in the art are used to label at least one of the component members of the complex. Suitable labeling methods include, but are not limited to, radiolabeling by incorporation of radiolabeled amino acids, *e.g.*,  $^3\text{H}$ -leucine or  $^{35}\text{S}$ -methionine, radiolabeling by post-translational iodination with  $^{125}\text{I}$  or  $^{131}\text{I}$  using the chloramine T method, Bolton-Hunter reagents, *etc.*, or labeling with  $^{32}\text{P}$  using phosphorylase and inorganic radiolabeled phosphorous, biotin labeling with photobiotin-acetate and sunlamp exposure, *etc.* In cases where one of the members of the complex is immobilized, *e.g.*, as described in section 4.5.1.1, the free species is labeled. Where neither of the interacting species is immobilized, each can be labeled with a distinguishable marker such that isolation of both moieties can be followed to provide for more accurate quantification, and to distinguish the formation of homomeric from heteromeric complexes. Methods that utilize accessory proteins that bind to one of the modified components to improve the sensitivity of detection, increase the stability of the complex, *etc.*, are provided.

The physical parameters of complex formation can be analyzed by quantification of complex formation using assay methods specific for the label used, *e.g.*, liquid scintillation counting for radioactivity detection, enzyme activity for enzyme-labeled moieties, etc. The reaction results are then analyzed utilizing Scatchard analysis, Hill analysis, and other methods commonly known in the arts (see, *e.g.*, Proteins, Structures, and Molecular Principles, 2<sup>nd</sup> Edition (1993) Creighton, Ed., W.H. Freeman and Company, New York).

Compounds to be screened can be provided as mixtures of a limited number of specified compounds, or as compound libraries, peptide libraries and the like.

Agents/molecules/compounds to be screened may also include all forms of antisera, antisense nucleic acids, etc., that can modulate complex activity or formation. Exemplary compounds and libraries for screening are set forth in section 4.5.12.

In a specific embodiment of the invention, compounds are identified that promote the formation of a complex comprising Sen2ΔEx8, Clp1, Sen54, Sen15, and Sen34 instead of a complex comprising Sen2ΔEx8, Clp1, Sen54, Sen15, Sen34, CPSF, CFIm, CFIIIm and CstF.

In certain embodiments, compounds are identified that promote the formation of a Sen2ΔEx8 containing complex but not the formation of a Sen2 containing complex. In certain embodiments, compounds are identified that promote the formation of a Sen2 containing complex but not the formation of a Sen2ΔEx8 containing complex.

In certain embodiments, the compounds are screened in pools. Once a positive pool has been identified, the individual molecules of that pool are tested separately. In certain embodiments, the pool size is at least 2, at least 5, at least 10, at least 25, at least 50, at least 75, at least 100, at least 150, at least 200, at least 250, or at least 500 compounds.

In certain embodiments of the invention, the screening method further comprises determining the structure of the candidate molecule. The structure of a candidate molecule can be determined by any technique known to the skilled artisan. Exemplary methods are described in section 0.

#### **4.5.1.1 CELL-FREE ASSAYS**

In certain embodiments, the method for identifying a modulator of the formation or stability of a complex of the invention can be carried out *in vitro*, particularly in a cell-free system. In certain, more specific embodiments, the complex is purified. In certain embodiments the candidate molecule is purified.

In a specific embodiment, screening can be carried out by contacting the library members with a complex immobilized on a solid phase, and harvesting those library members that bind to the protein (or encoding nucleic acid or derivative). Examples of such screening methods, termed "panning" techniques, are described by way of example in Parmley and Smith,  
5 1988, Gene 73:305-318; Fowlkes et al., 1992, BioTechniques 13:422-427; International Patent Publication No. WO 94/18318; and in references cited hereinabove.

In one embodiment, agents that modulate (*i.e.*, antagonize or agonize) complex activity or formation can be screened for using a binding inhibition assay, wherein agents are screened for their ability to modulate formation of a complex under aqueous, or physiological, binding  
10 conditions in which complex formation occurs in the absence of the agent to be tested. Agents that interfere with the formation of complexes of the invention are identified as antagonists of complex formation. Agents that promote the formation of complexes are identified as agonists of complex formation. Agents that completely block the formation of complexes are identified as inhibitors of complex formation. In an exemplary embodiment, the binding conditions are,  
15 for example, but not by way of limitation, in an aqueous salt solution of 10-250 mM NaCl, 5-50 mM Tris-HCl, pH 5-8, and 0.5% Triton X-100 or other detergent that improves specificity of interaction. Metal chelators and/or divalent cations may be added to improve binding and/or reduce proteolysis. Reaction temperatures may include 4, 10, 15, 22, 25, 35, or 42 degrees Celsius, and time of incubation is typically at least 15 seconds, but longer times are preferred to  
20 allow binding equilibrium to occur. Particular complexes can be assayed using routine protein binding assays to determine optimal binding conditions for reproducible binding.

In certain embodiments, another common approach to *in vitro* binding assays is used. In this assay, one of the binding species is immobilized on a filter, in a microtiter plate well, in a test tube, to a chromatography matrix, etc., either covalently or non-covalently. Proteins can be  
25 covalently immobilized using any method well known in the art, for example, but not limited to the method of Kadonaga and Tjian, 1986, Proc. Natl. Acad. Sci. USA 83:5889-5893, *i.e.*, linkage to a cyanogen-bromide derivatized substrate such as CNBr-Sepharose 4B (Pharmacia). Where needed, the use of spacers can reduce steric hindrance by the substrate. Non-covalent attachment of proteins to a substrate include, but are not limited to, attachment of a protein to a  
30 charged surface, binding with specific antibodies, binding to a third unrelated interacting protein, *etc.*

Assays of agents (including cell extracts or a library pool) for competition for binding of one member of a complex (or derivatives thereof) with another member of the complex labeled by any means (*e.g.*, those means described above) are provided to screen for competitors or

enhancers of complex formation. In specific embodiments, blocking agents to inhibit non-specific binding of reagents to other protein components, or absorptive losses of reagents to plastics, immobilization matrices, *etc.*, are included in the assay mixture. Blocking agents include, but are not restricted to bovine serum albumin, beta-casein, nonfat dried milk,

- 5 Denhardt's reagent, Ficoll, polyvinylpyrrolidone, nonionic detergents (NP40, Triton X-100, Tween 20, Tween 80, *etc.*), ionic detergents (*e.g.*, SDS, LDS, *etc.*), polyethylene glycol, *etc.* Appropriate blocking agent concentrations allow complex formation.

After binding is performed, unbound, labeled protein is removed in the supernatant, and the immobilized protein retaining any bound, labeled protein is washed extensively. The  
10 amount of bound label is then quantified using standard methods in the art to detect the label.

In preferred embodiments, polypeptide derivatives that have superior stabilities but retain the ability to form a complex (*e.g.*, one or more component proteins modified to be resistant to proteolytic degradation in the binding assay buffers, or to be resistant to oxidative degradation), are used to screen for modulators of complex activity or formation. Such resistant molecules  
15 can be generated, *e.g.*, by substitution of amino acids at proteolytic cleavage sites, the use of chemically derivatized amino acids at proteolytic susceptible sites, and the replacement of amino acid residues subject to oxidation, *i.e.* methionine and cysteine.

#### 4.5.1.2 CELL-BASED ASSAYS

20 In certain embodiments, assays can be carried out using recombinant cells expressing the protein components of a complex, to screen for molecules that bind to, or interfere with, or promote complex activity or formation. In certain embodiments, at least one of the protein components is expressed in the recombinant cell as fusion protein, wherein the protein component is fused to a peptide tag to facilitate purification and subsequent quantification  
25 and/or immunological visualization and quantification.

A particular aspect of the present invention relates to identifying molecules that inhibit or promote formation or degradation of a complex of the present invention, *e.g.*, using the method described for isolating the complex and identifying members of the complex using the TAP assay described in WO 00/09716 and Rigaut *et al.*, 1999, Nature Biotechnology 17:1030-1032,  
30 which are each incorporated by reference in their entireties.

In another embodiment of the invention, a modulator is identified by administering a candidate molecule to a transgenic non-human animal expressing the recombinant component proteins of a complex of the invention. In certain embodiments, the complex components are

distinguishable from the homologous endogenous protein components. In certain embodiments, the recombinant component proteins are fusion proteins, wherein the protein component is fused to a peptide tag. In certain embodiments, the amino acid sequence of the recombinant protein component is different from the amino acid sequence of the endogenous protein component such that antibodies specific to the recombinant protein component can be used to determine the level of the protein component or the complex formed with the component. In certain embodiments, the recombinant protein component is expressed from promoters that are not the native promoters of the respective proteins. In a specific embodiment, the recombinant protein component is expressed in tissues where it is normally not expressed. In a specific embodiment, the compound is also recombinantly expressed in the transgenic non-human animal.

In certain embodiments, a mutant form of a protein component of a complex of the invention is expressed in a cell, wherein the mutant form of the protein component has a binding affinity that is lower than the binding affinity of the naturally occurring protein to the other protein component of a complex of the invention. In a specific embodiment, a dominant negative mutant form of a protein component is expressed in a cell. A dominant negative form can be the domain of the protein component that binds to the other protein component, *i.e.*, the binding domain. Without being bound by theory, the binding domain will compete with the naturally occurring protein component for binding to the other protein component of the complex thereby preventing the formation of complex that contains full length protein components. Instead, with increasing level of the dominant negative form in the cell, an increasing amount of complex lacks those domains that are normally provided to the complex by the protein component which is expressed as dominant negative.

The binding domain of a protein component can be identified by any standard technique known to the skilled artisan. In a non-limiting example, alanine-scanning mutagenesis (Cunningham and Wells, Science 244:1081-1085 (1989)) is conducted to identify the region(s) of the protein that is/are required for dimerization with another protein component. In other embodiments, different deletion mutants of the protein component are generated such that the combined deleted regions would span the entire protein. In a specific embodiment, the different deletions overlap with each other. Once mutant forms of a protein component are generated, they are tested for their ability to form a dimer with another protein component. If a particular mutant fails to form a dimer with another protein component or binds the other protein component with reduced affinity compared to the naturally occurring form, the mutation of this mutant form is identified as being in a region of the protein that is involved in the dimer formation. To exclude that the mutation simply interfered with proper folding of the protein,



any structural analysis known to the skilled artisan can be performed to determine the 3-dimensional conformation of the protein. Such techniques include, but are not limited to, circular dichroism (CD), NMR, and x-ray cristallography.

In certain embodiments, a mutated form of a component of a complex of the invention can be expressed in a cell under an inducible promoter. Any method known to the skilled artisan can be used to mutate the nucleotide sequence encoding the component. Any inducible promoter known to the skilled artisan can be used. In particular, the mutated form of the component of a complex of the invention has reduced activity, *e.g.*, reduced RNA-nucleolytic activity and/or reduced affinity to the other components of the complex.

In certain embodiments, the assays of the invention are performed in high-throughput format.

#### **4.5.2 Use Of Complexes To Identify New Binding Partners**

In certain embodiments of the invention, a complex of the invention is used to identify new components the complex. In certain embodiments, new binding partners of a complex of the invention are identified and thereby implicated in RNA processing. Any technique known to the skilled artisan can be used to identify such new binding partners. In certain embodiments, a binding partner of a complex of the invention binds to a complex of the invention but not to an individual protein component of a complex of the invention. In a specific embodiment, immunoprecipitation is used to identify binding partners of a complex of the invention.

In certain embodiments, the assays of the invention are performed in high-throughput format.

#### **4.5.3 Use Of Complexes To Identify Pre-Mature Stop Codons And Modulators Thereof**

In certain embodiments of the invention, a complex of the invention is used to cleave an mRNA or pre-mRNA molecule containing a pre-mature stop codon. In certain, more specific, embodiments of the invention, a complex of the invention is used to cleave an mRNA or pre-mRNA molecule at or in the vicinity of a pre-mature stop codon. Without being bound by theory, a complex of the invention cleaves an mRNA or a pre-mRNA molecule at or in the vicinity of a pre-mature stop codon. In certain embodiments, the complex of the invention cleaves an mRNA or a pre-mRNA molecule within 500, 400, 300, 200, 100 or 50 nucleotides of the pre-mature stop codon. In certain embodiments, the complex of the invention cleaves an

mRNA or a pre-mRNA molecule within 1 to 50, 1 to 100, 1 to 250, 1 to 500, 10 to 50, 10 to 100, 25 to 100, 50 to 100, 50 to 250, 50 to 500, 100 to 500, or 250 to 500 nucleotides of the pre-mature stop codon.

In certain embodiments of the invention, a complex of the invention is used to identify pre-mature stop codons in an mRNA or pre-mRNA molecule. In certain embodiments, the complex of the invention cleaves an mRNA or a pre-mRNA molecule within 500, 400, 300, 200, 100 or 50 nucleotides of the pre-mature stop codon. In certain embodiments, the complex of the invention cleaves an mRNA or a pre-mRNA molecule within 1 to 50, 1 to 100, 1 to 250, 1 to 500, 10 to 50, 10 to 100, 25 to 100, 50 to 100, 50 to 250, 50 to 500, 100 to 500, or 250 to 500 nucleotides of the pre-mature stop codon.

To identify the pre-mature stop codon, an mRNA or pre-mRNA of interest is incubated with a complex of the invention under conditions conducive to cleavage of the mRNA or pre-mRNA by the complex. Once cleavage occurred, the cleavage products are analyzed to determine the location of the cleavage site. The location of the cleavage site can be determined by any method known to the skilled artisan, such as, but not limited to Northern blot analysis.

In certain embodiments, the complexes of the invention can be used to identify modulators of cleavage of pre-mature stop codons by a complex of the invention. In certain embodiments, a complex of the invention is incubated with an mRNA or pre-mRNA of interest under conditions conducive to cleavage of the mRNA or pre-mRNA by the complex in the presence of a compound, wherein the mRNA or pre-mRNA is known to have a pre-mature stop codon. If the compound increases the amount of cleavage product generated, the compound is identified as an activator of the pre-mature stop codon cleavage activity of a complex of the invention. If the compound decreases the amount of cleavage product generated, the compound is identified as an inhibitor of the pre-mature stop codon cleavage activity of a complex of the invention.

In certain embodiments, the assays of the invention are performed in high-throughput format.

#### **4.5.4 Modulators of Complex Function**

Any method known to the skilled artisan can be used to identify compound that modulate the activity of a complex of the invention. In certain embodiments, compounds can be identified that modulate the activity of a pre-tRNA splicing endonuclease complex. In other embodiments, compounds can be identified using the methods of the invention that modulate the activity of a 3'

end pre-mRNA processing complex. In even other embodiments, compounds can be identified using the methods of the invention that modulate the activity of a pre-tRNA cleavage complex. In yet other embodiments, compounds can be identified using the methods of the invention that modulate the activity of a complex involved in the biogenesis of mature ribosomal RNAs from precursor ribosomal RNA.

In certain embodiments, the substrate of the pre-tRNA splicing endonuclease complex or the 3' end pre-mRNA endonuclease complex comprises a reporter gene such that the endonuclease reaction results either in increased or decreased expression of the reporter gene. Any reporter gene can be used with the methods of the invention. Exemplary methods are set forth below. The substrate of the pre-tRNA splicing endonuclease complex, the 3' end pre-mRNA endonuclease complex, pre-tRNA cleavage complex or the complex involved in the biogenesis of mature ribosomal RNAs from precursor ribosomal RNA can be an RNA molecule that is detectably labeled and that is known to be cleaved by the complex. The complex and its substrate are then incubated under conditions conducive to the cleavage of the substrate by the complex and subsequently the activity is evaluated by measuring the amount of substrate and/or cleavage product. See, *e.g.*, section 4.5.4.1.

In certain embodiments, the assays of the invention are performed in high-throughput format.

Various *in vitro* assays can be used to identify and verify the ability of a compound to modulate the activity of a pre-tRNA splicing endonuclease complex or a 3' end pre-mRNA endonuclease complex. Multiple *in vitro* assays can be performed simultaneously or sequentially to assess the affect of a compound on the activity of a human tRNA splicing endonuclease.

In certain embodiments, the pre-tRNA splicing endonuclease complex is incubated with a detectably labeled pre-tRNA substrate under conditions conducive to the endonuclease reaction. After a period of time, the reaction is stopped and the RNA is resolved using PAGE. In certain embodiments, the RNA is precipitated from the reaction before the RNA is resolved on the gel. The amount of cleavage product can be determined based on the different length between substrate and product. In certain embodiments, the RNA substrate is radioactively labeled and can be detected using autoradiography. The more active the pre-tRNA splicing endonuclease complex is the more cleavage product relative to the substrate is detected.

In certain embodiments, the 3' end pre-mRNA endonuclease complex is incubated with a detectably labeled 3' end pre-mRNA substrate under conditions conducive to the endonuclease

reaction. After a period of time, the reaction is stopped and the RNA is resolved using PAGE. In certain embodiments, the RNA is precipitated from the reaction before the RNA is resolved on the gel. The amount of cleavage product can be determined based on the different length between substrate and product. In certain embodiments, the RNA substrate is radioactively  
5 labeled and can be detected using autoradiography. The more active the 3' end pre-mRNA endonuclease complex is the more cleavage product relative to the substrate is detected. Such an assay can analogously be used to identify modulators of tRNA splicing endonuclease, rRNA endonuclease or tRNA cleavage activity.

To identify compounds that modulate the 3' end pre-mRNA endonuclease activity  
10 of a complex of the invention, the complex can be incubated with its substrate, wherein the substrate is detectably labeled. In certain, more specific embodiments, the detectable label is a radioactive label, such as, but not limited to,  $^{33}\text{P}$  or  $^{32}\text{P}$ . In other embodiments, the label is a fluorescent label. The detectably labeled substrate is incubated with the 3' end pre-mRNA endonuclease under conditions conducive to the cleavage of the pre-mRNA substrate by the 3'  
15 end pre-mRNA endonuclease. The detectably labeled substrate can be microinjected into a cell or transfected into a cell. The substrate can be incubated with cell extract or the substrate can be incubated with purified 3' end pre-mRNA endonuclease complex. After a time sufficient for the cleavage reaction to take place, the substrate is resolved using PAGE and the reaction product and any remaining substrate is visualized. If the substrate is labeled radioactively, the reaction  
20 product can be visualized using autoradiography. In certain embodiments, the time for incubating is at least 1min, 5min, 10min, 30min, 45min, 1h, 2h, 4h, 6h, 8h, 10h, 12h, 18h, or at least 14h. Such an assay can analogously be used to identify modulators of tRNA endonuclease, rRNA endonuclease or tRNA splicing endonuclease activity.

To identify compounds that modulate the tRNA cleavage activity of a complex of the  
25 invention or the activity of a complex of the invention in the biogenesis of mature ribosomal RNAs from precursor ribosomal RNA, the complex can be incubated with its substrate, wherein the substrate is detectably labeled. In certain embodiments, a complex with tRNA cleavage activity or a complex involved in the biogenesis of mature ribosomal RNAs from precursor ribosomal RNA are incubated under conditions conducive to the cleavage of the substrate by the  
30 complex and subsequently the activity is evaluated by measuring the amount of substrate and/or cleavage product. The complex and substrate can be incubated in the presence and absence of a compound and the effect of the compound on the RNA-nucleolytic activity of the complex is determined. In other embodiments, a pre-tRNA or a pre-rRNA is incubated with a complex of the invention to determine where cleavage sites are present in the RNA.

In certain specific embodiments, the assay is performed concurrently with a control, *i.e.*, the assay is performed in the presence and the absence of a compound to determine the effect of the compound on the endonuclease reaction. The assay can include steps in the presence and the absence of a compound to determine the effect of the compound on the endonuclease reaction.

5 In other embodiments, a historic value is used for comparison.

In certain embodiments, the invention provides a method comprising: (i) identifying a compound as a modulator of tRNA splicing activity, 3' end pre-mRNA endonuclease activity, and/or pre-tRNA cleavage activity in a cell-based assay, *e.g.*, as described below; and (ii) testing the compound identified in step (i) for its ability to modify tRNA splicing activity, 3' end pre-mRNA endonuclease activity, and/or pre-tRNA cleavage activity in a cell-free assay using a  
10 purified complex of the invention.

Assays for tRNA endonuclease activity can be used to determine tRNA cleavage activity.

#### 15 4.5.4.1 Reporter Gene Constructs, Transfected Cells and Cell Extracts

The invention provides for specific vectors comprising a reporter gene comprising a tRNA intron operably linked to one or more regulatory elements and host cells transfected with the vectors if tRNA endonuclease activity is to be tested. If 3' end pre-mRNA endonuclease activity is to be tested, the substrate comprises a 3' end pre-mRNA reporter (see section  
20 4.5.4.1.3). The invention also provides for the *in vitro* translation of a reporter gene flanked by one or more regulatory elements. Techniques for practicing this specific aspect of this invention will employ, unless otherwise indicated, conventional techniques of molecular biology, microbiology, and recombinant DNA manipulation and production, which are routinely practiced by one of skill in the art. See, *e.g.*, Sambrook, 1989, Molecular Cloning, A Laboratory  
25 Manual, Second Edition; DNA Cloning, Volumes I and II (Glover, Ed. 1985); Oligonucleotide Synthesis (Gait, Ed. 1984); Nucleic Acid Hybridization (Hames & Higgins, Eds. 1984); Transcription and Translation (Hames & Higgins, Eds. 1984); Animal Cell Culture (Freshney, Ed. 1986); Immobilized Cells and Enzymes (IRL Press, 1986); Perbal, A Practical Guide to Molecular Cloning (1984); Gene Transfer Vectors for Mammalian Cells (Miller & Calos, Eds.  
30 1987, Cold Spring Harbor Laboratory); Methods in Enzymology, Volumes 154 and 155 (Wu & Grossman, and Wu, Eds., respectively), (Mayer & Walker, Eds., 1987); Immunochemical Methods in Cell and Molecular Biology (Academic Press, London, Scopes, 1987), Expression of

Proteins in Mammalian Cells Using Vaccinia Viral Vectors in Current Protocols in Molecular Biology, Volume 2 (Ausubel et al., Eds., 1991).

#### 4.5.4.1.1 Reporter Genes

5 Any reporter gene well-known to one of skill in the art may be used in reporter gene constructs to ascertain the effect of a compound on a tRNA endonuclease complex or a 3' end pre-mRNA endonuclease. Reporter genes refer to a nucleotide sequence encoding a protein that is readily detectable either by its presence or activity. Reporter genes may be obtained and the nucleotide sequence of the elements determined by any method well-known to one of skill in the art. The nucleotide sequence of a reporter gene can be obtained, *e.g.*, from the literature or a database such as GenBank. Alternatively, a polynucleotide encoding a reporter gene may be generated from nucleic acid from a suitable source. If a clone containing a nucleic acid encoding a particular reporter gene is not available, but the sequence of the reporter gene is known, a nucleic acid encoding the reporter gene may be chemically synthesized or obtained from a suitable source (*e.g.*, a cDNA library, or a cDNA library generated from, or nucleic acid, preferably poly A+ RNA, isolated from, any tissue or cells expressing the reporter gene) by PCR amplification. Once the nucleotide sequence of a reporter gene is determined, the nucleotide sequence of the reporter gene may be manipulated using methods well-known in the art for the manipulation of nucleotide sequences, *e.g.*, recombinant DNA techniques, site directed mutagenesis, PCR, etc. (see, for example, the techniques described in Sambrook et al., 1990, Molecular Cloning, A Laboratory Manual, 2d Ed., Cold Spring Harbor Laboratory, Cold Spring Harbor, NY and Ausubel *et al.*, eds., 1998, Current Protocols in Molecular Biology, John Wiley & Sons, NY, which are both incorporated by reference herein in their entireties), to generate reporter genes having a different amino acid sequence, for example to create amino acid substitutions, deletions, and/or insertions.

Examples of reporter genes include, but are not limited to, luciferase (*e.g.*, firefly luciferase, renilla luciferase, and click beetle luciferase), green fluorescent protein ("GFP") (*e.g.*, green fluorescent protein, yellow fluorescent protein, red fluorescent protein, cyan fluorescent protein, and blue fluorescent protein), beta-galactosidase ("beta-gal"), beta-glucoronidase, beta-lactamase, chloramphenicol acetyltransferase ("CAT"), and alkaline phosphatase ("AP"). Table 2 below lists various reporter genes and the properties of the products of the reporter genes that can be assayed. In a preferred embodiment, a reporter gene utilized in the reporter

constructs is easily assayed and has an activity which is not normally found in the cell or organism of interest.

TABLE 2: Reporter Genes and the Properties of the Reporter Gene Products

Reporter Gene	Protein Activity & Measurement
CAT (chloramphenicol acetyltransferase)	Transfers radioactive acetyl groups to chloramphenicol or detection by thin layer chromatography and autoradiography
GAL (beta-galactosidase)	Hydrolyzes colorless galactosides to yield colored products.
GUS (beta-glucuronidase)	Hydrolyzes colorless glucuronides to yield colored products.
LUC (luciferase)	Oxidizes luciferin, emitting photons
GFP (green fluorescent protein)	Fluorescent protein without substrate
SEAP (secreted alkaline phosphatase)	Luminescence reaction with suitable substrates or with substrates that generate chromophores
HRP (horseradish peroxidase)	In the presence of hydrogen oxide, oxidation of 3,3',5,5'-tetramethylbenzidine to form a colored complex
AP (alkaline phosphatase)	Luminescence reaction with suitable substrates or with substrates that generate chromophores

Described hereinbelow in further detailed are specific reporter genes and characteristics of those reporter genes.

10

### **Luciferase**

Luciferases are enzymes that emit light in the presence of oxygen and a substrate (luciferin) and which have been used for real-time, low-light imaging of gene expression in cell cultures, individual cells, whole organisms, and transgenic organisms (reviewed by Greer & Szalay, 2002, *Luminescence* 17(1):43-74).

15

As used herein, the term "luciferase" is intended to embrace all luciferases, or recombinant enzymes derived from luciferases which have luciferase activity. The luciferase genes from fireflies have been well characterized, for example, from the *Photinus* and

*Luciola* species (see, *e.g.*, International Patent Publication No. WO 95/25798 for *Photinus pyralis*, European Patent Application No. EP 0 524 448 for *Luciola cruciata* and *Luciola lateralis*, and Devine et al., 1993, Biochim. Biophys. Acta 1173(2):121-132 for *Luciola mingrelica*). Other eucaryotic luciferase genes include, but are not limited to, the click beetle (*Photinus plagiophthalmus*, see, *e.g.*, Wood et al., 1989, Science 244:700-702), the sea panzy (*Renilla reniformis*, see, *e.g.*, Lorenz et al., 1991, Proc Natl Acad Sci U S A 88(10):4438-4442), and the glow worm (*Lampyrus noctiluca*, see *e.g.*, Sula-Newby et al., 1996, Biochem J. 313:761-767). The click beetle is unusual in that different members of the species emit bioluminescence of different colors, which emit light at 546 nm (green), 560 nm (yellow-green), 578 nm (yellow) and 593 nm (orange) (see, *e.g.*, U.S. Patent Nos. 6,475,719; 6,342,379; and 6,217,847, the disclosures of which are incorporated by reference in their entireties). Bacterial luciferin-luciferase systems include, but are not limited to, the bacterial lux genes of terrestrial *Photorhabdus luminescens* (see, *e.g.*, Manukhov et al., 2000, Genetika 36(3):322-30) and marine bacteria *Vibrio fischeri* and *Vibrio harveyi* (see, *e.g.*, Miyamoto et al., 1988, J Biol Chem. 263(26):13393-9, and Cohn et al., 1983, Proc Natl Acad Sci USA., 80(1):120-3, respectively). The luciferases encompassed by the present invention also includes the mutant luciferases described in U.S. Patent No. 6,265,177 to Squirrell *et al.*, which is hereby incorporated by reference in its entirety.

In a preferred embodiment, the luciferase is a firefly luciferase, a renilla luciferase, or a click beetle luciferase, as described in any one of the references listed *supra*, the disclosures of which are incorporated by reference in their entireties.

## **Green Fluorescent Protein**

Green fluorescent protein ("GFP") is a 238 amino acid protein with amino acid residues 65 to 67 involved in the formation of the chromophore which does not require additional substrates or cofactors to fluoresce (see, *e.g.*, Prasher et al., 1992, Gene 111:229-233; Yang et al., 1996, Nature Biotechnol. 14:1252-1256; and Cody et al., 1993, Biochemistry 32:1212-1218).

As used herein, the term "green fluorescent protein" or "GFP" is intended to embrace all GFPs (including the various forms of GFPs which exhibit colors other than green), or



recombinant enzymes derived from GFPs which have GFP activity. In a preferred embodiment, GFP includes green fluorescent protein, yellow fluorescent protein, red fluorescent protein, cyan fluorescent protein, and blue fluorescent protein. The native gene for GFP was cloned from the bioluminescent jellyfish *Aequorea victoria* (see, e.g., Morin et al., 1972, J. Cell Physiol. 77:313-318). Wild type GFP has a major excitation peak at 395 nm and a minor excitation peak at 470 nm. The absorption peak at 470 nm allows the monitoring of GFP levels using standard fluorescein isothiocyanate (FITC) filter sets. Mutants of the GFP gene have been found useful to enhance expression and to modify excitation and fluorescence. For example, mutant GFPs with alanine, glycine, isoleucine, or threonine substituted for serine at position 65 result in mutant GFPs with shifts in excitation maxima and greater fluorescence than wild type protein when excited at 488 nm (see, e.g., Heim et al., 1995, Nature 373:663-664; U.S. Patent No. 5,625,048; Delagrave et al., 1995, Biotechnology 13:151-154; Cormack et al., 1996, Gene 173:33-38; and Cramer et al., 1996, Nature Biotechnol. 14:315-319). The ability to excite GFP at 488 nm permits the use of GFP with standard fluorescence activated cell sorting ("FACS") equipment. In another embodiment, GFPs are isolated from organisms other than the jellyfish, such as, but not limited to, the sea pansy, *Renilla reniformis*.

Techniques for labeling cells with GFP in general are described in U.S. Patent Nos. 5,491,084 and 5,804,387, which are incorporated by reference in their entireties; Chalfie et al., 1994, Science 263:802-805; Heim et al., 1994, Proc. Natl. Acad. Sci. USA 91:12501-12504; Morise et al., 1974, Biochemistry 13:2656-2662; Ward et al., 1980, Photochem. Photobiol. 31:611-615; Rizzuto et al., 1995, Curr. Biology 5:635-642; and Kaether & Gerdes, 1995, FEBS Lett 369:267-271. The expression of GFPs in *E. coli* and *C. elegans* are described in U.S. Patent No. 6,251,384 to Tan et al., which is incorporated by reference in its entirety. The expression of GFP in plant cells is discussed in Hu & Cheng, 1995, FEBS Lett 369:331-33, and GFP expression in *Drosophila* is described in Davis et al., 1995, Dev. Biology 170:726-729.

### **Beta-galactosidase**

Beta galactosidase ("beta-gal") is an enzyme that catalyzes the hydrolysis of beta-galactosides, including lactose, and the galactoside analogs o-nitrophenyl-beta-D-galactopyranoside ("ONPG") and chlorophenol red-beta-D-galactopyranoside ("CPRG") (see, e.g., Nielsen et al., 1983 Proc Natl Acad Sci USA 80(17):5198-5202; Eustice et al., 1991, Biotechniques 11:739-742; and Henderson et al., 1986, Clin. Chem. 32:1637-1641). The beta-

gal gene functions well as a reporter gene because the protein product is extremely stable, resistant to proteolytic degradation in cellular lysates, and easily assayed. When ONPG is used as the substrate, beta-gal activity can be quantitated with a spectrophotometer or microplate reader.

5 As used herein, the term "beta galactosidase" or "beta-gal" is intended to embrace all beta-gals, including *lacZ* gene products, or recombinant enzymes derived from beta-gals which have beta-gal activity. The beta-gal gene functions well as a reporter gene because the protein product is extremely stable, resistant to proteolytic degradation in cellular lysates, and easily assayed. In an embodiment where ONPG is the substrate, beta-gal activity can be quantitated  
10 with a spectrophotometer or microplate reader to determine the amount of ONPG converted at 420 nm. In an embodiment when CPRG is the substrate, beta-gal activity can be quantitated with a spectrophotometer or microplate reader to determine the amount of CPRG converted at 570 to 595 nm. In yet another embodiment, the beta-gal activity can be visually ascertained by plating bacterial cells transformed with a beta-gal construct onto plates containing Xgal and  
15 IPTG. Bacterial colonies that are dark blue indicate the presence of high beta-gal activity and colonies that are varying shades of blue indicate varying levels of beta-gal activity.

#### **Beta-glucuronidase**

Beta-glucuronidase ("GUS") catalyzes the hydrolysis of a very wide variety of beta-glucuronides, and, with much lower efficiency, hydrolyzes some beta-galacturonides. GUS is  
20 very stable, will tolerate many detergents and widely varying ionic conditions, has no cofactors, nor any ionic requirements, can be assayed at any physiological pH, with an optimum between 5.0 and 7.8, and is reasonably resistant to thermal inactivation (see, *e.g.*, U.S. Patent No. 5,268,463, which is incorporated by reference in its entirety).

In one embodiment, the GUS is derived from the *Escherichia coli* beta-glucuronidase  
25 gene. In alternate embodiments of the invention, the beta-glucuronidase encoding nucleic acid is homologous to the *E. coli* beta-glucuronidase gene and/or may be derived from another organism or species.

GUS activity can be assayed either by fluorescence or spectrometry, or any other method described in U.S. Patent No. 5,268,463, the disclosure of which is incorporated by reference in  
30 its entirety. For a fluorescent assay, 4-trifluoromethylumbelliferyl beta-D-glucuronide is a very sensitive substrate for GUS. The fluorescence maximum is close to 500 nm--bluish green, where very few plant compounds fluoresce or absorb. 4-trifluoromethylumbelliferyl beta-D-

glucuronide also fluoresces much more strongly near neutral pH, allowing continuous assays to be performed more readily than with MUG. 4-trifluoromethylumbelliferyl beta-D-glucuronide can be used as a fluorescent indicator *in vivo*. The spectrophotometric assay is very straightforward and moderately sensitive (Jefferson et al., 1986, Proc. Natl. Acad. Sci. USA 86:8447-8451). A preferred substrate for spectrophotometric measurement is p-nitrophenyl beta-D-glucuronide, which when cleaved by GUS releases the chromophore p-nitrophenol. At a pH greater than its pK<sub>a</sub> (around 7.15) the ionized chromophore absorbs light at 400-420 nm, giving a yellow color.

### **Beta-lactamase**

Beta-lactamases are nearly optimal enzymes in respect to their almost diffusion-controlled catalysis of beta-lactam hydrolysis, making them suited to the task of an intracellular reporter enzyme (see, *e.g.*, Christensen et al., 1990, Biochem. J. 266: 853-861). They cleave the beta-lactam ring of beta-lactam antibiotics, such as penicillins and cephalosporins, generating new charged moieties in the process (see, *e.g.*, O'Callaghan et al., 1968, Antimicrob. Agents. Chemother. 8: 57-63 and Stratton, 1988, J. Antimicrob. Chemother. 22, Suppl. A: 23-35). A large number of beta-lactamases have been isolated and characterized, all of which would be suitable for use in accordance with the present invention (see, *e.g.*, Richmond & Sykes, 1978, Adv. Microb. Physiol. 9:31-88 and Ambler, 1980, Phil. Trans. R. Soc. Lond. [Ser.B.] 289: 321-331, the disclosures of which are incorporated by reference in their entireties).

The coding region of an exemplary beta-lactamase employed has been described in U.S. Patent No. 6,472,205, Kadonaga et al., 1984, J. Biol. Chem. 259: 2149-2154, and Sutcliffe, 1978, Proc. Natl. Acad. Sci. USA 75: 3737-3741, the disclosures of which are incorporated by reference in their entireties. As would be readily apparent to those skilled in the field, this and other comparable sequences for peptides having beta-lactamase activity would be equally suitable for use in accordance with the present invention. The combination of a fluorogenic substrate described in U.S. Patent Nos. 6,472,205, 5,955,604, and 5,741,657, the disclosures of which are incorporated by reference in their entireties, and a suitable beta-lactamase can be employed in a wide variety of different assay systems, such as are described in U.S. Patent No. 4,740,459, which is hereby incorporated by reference in its entirety.

### **Chloramphenicol Acetyltransferase**

Chloramphenicol acetyl transferase ("CAT") is commonly used as a reporter gene in mammalian cell systems because mammalian cells do not have detectable levels of CAT

activity. The assay for CAT involves incubating cellular extracts with radiolabeled chloramphenicol and appropriate co-factors, separating the starting materials from the product by, for example, thin layer chromatography ("TLC"), followed by scintillation counting (see, e.g., U.S. Patent No. 5,726,041, which is hereby incorporated by reference in its entirety).

5 As used herein, the term "chloramphenicol acetyltransferase" or "CAT" is intended to embrace all CATs, or recombinant enzymes derived from CAT which have CAT activity. While it is preferable that a reporter system which does not require cell processing, radioisotopes, and chromatographic separations would be more amenable to high through-put screening, CAT as a reporter gene may be preferable in situations when stability of the reporter  
10 gene is important. For example, the CAT reporter protein has an *in vivo* half life of about 50 hours, which is advantageous when an accumulative versus a dynamic change type of result is desired.

#### **Secreted Alkaline Phosphatase**

The secreted alkaline phosphatase ("SEAP") enzyme is a truncated form of alkaline  
15 phosphatase, in which the cleavage of the transmembrane domain of the protein allows it to be secreted from the cells into the surrounding media. In a preferred embodiment, the alkaline phosphatase is isolated from human placenta.

As used herein, the term "secreted alkaline phosphatase" or "SEAP" is intended to embrace all SEAP or recombinant enzymes derived from SEAP which have alkaline  
20 phosphatase activity. SEAP activity can be detected by a variety of methods including, but not limited to, measurement of catalysis of a fluorescent substrate, immunoprecipitation, HPLC, and radiometric detection. The luminescent method is preferred due to its increased sensitivity over calorimetric detection methods. The advantages of using SEAP is that a cell lysis step is not required since the SEAP protein is secreted out of the cell, which facilitates the automation of  
25 sampling and assay procedures. A cell-based assay using SEAP for use in cell-based assessment of inhibitors of the Hepatitis C virus protease is described in U.S. Patent No. 6,280,940 to Potts et al. which is hereby incorporated by reference in its entirety.

#### **4.5.4.1.2 tRNA Introns**

30 Any nucleotide sequence recognized and excised by a tRNA splicing endonuclease complex may be inserted into the coding region of a reporter gene such that the mRNA coding the reporter gene out of frame utilizing well-known molecular biology techniques. For example,

a nucleotide sequence comprising a bulge-helix-bulge structure or a mature domain of a precursor tRNA may be inserted into the coding region of a reporter gene such that the mRNA coding the reporter gene out of frame. Alternatively, a nucleotide sequence recognized and excised by a tRNA splicing endonuclease complex may be inserted into the 5' untranslated region, 3' untranslated region or both the 5' and 3' untranslated regions of a reporter gene construct. A nucleotide sequence recognized and excised by a tRNA splicing endonuclease complex may comprise 10 nucleotides, 15 nucleotides, 20 nucleotides, 25 nucleotides, 25 nucleotides, 30 nucleotides, 40 nucleotides, 45 nucleotides, 50 nucleotides, 55 nucleotides, 60 nucleotides, 65 nucleotides, 75 nucleotides, 100 nucleotides, 125 nucleotides, 150 nucleotides, or more. In certain embodiments, the nucleotide sequence is at least 10 nucleotides in length.

In a specific embodiment, a tRNA intron is inserted within the open reading frame of a reporter gene. In another embodiment, two, three, four, five or more tRNA introns are inserted within the open reading frame of a reporter gene. In an alternative embodiment, a tRNA intron is inserted within the 5' untranslated region, 3' untranslated region or both the 5' and 3' untranslated region of a reporter gene construct. In an alternative embodiment, two, three, four, five or more tRNA introns are inserted within the 5' untranslated region, 3' untranslated region or both the 5' and 3' untranslated region of a reporter gene construct. The tRNA intron may comprise a bulge-helix-bulge conformation.

A reporter gene containing a tRNA intron may be produced by any method well-known to one of skill in the art. For example, the reporter gene containing a tRNA intron may be chemically synthesized using phosphoramidite or other solution or solid-phase methods. Detailed descriptions of the chemistry used to form polynucleotides by the phosphoramidite method are well known (*see, e.g.,* Caruthers *et al.*, U.S. Pat. Nos. 4,458,066 and 4,415,732; Caruthers *et al.*, 1982, Genetic Engineering 4:1-17; *Users Manual Model 392 and 394 Polynucleotide Synthesizers*, 1990, pages 6-1 through 6-22, Applied Biosystems, Part No. 901237; Ojwang, *et al.*, 1997, Biochemistry, 36:6033-6045). After synthesis, the reporter gene containing a tRNA intron can be purified using standard techniques known to those skilled in the art (*see* Hwang *et al.*, 1999, Proc. Natl. Acad. Sci. USA 96(23):12997-13002 and references cited therein). Depending on the length of the reporter gene containing a tRNA intron and the method of its synthesis, such purification techniques include, but are not limited to, reverse-phase high-performance liquid chromatography ("reverse-phase HPLC"), fast performance liquid chromatography ("FPLC"), and gel purification. Methods for labeling the substrate with a fluorescent acceptor moiety, a fluorescent donor moiety and/or quencher are well-known in the

art (see, *e.g.*, U.S. Patent Nos. 6,472,156, 6,451,543, 6,348,322, 6,342,379, 6,323,039, 6,297,018, 6,291,201, 6,280,981, 5,843,658, and 5,439,797, the disclosures of which are incorporated by reference in their entirety).

5           **4.5.4.1.3        3' end pre-mRNA Cleavage Site**

3' end pre-mRNA endonuclease cleaves pre-mRNA at the 3' end to give rise to a 3' end of the mRNA that is subsequently polyadenylated. The cleavage and polyadenylation site is located between a conserved hexanucleotide, AAUAAA, upstream and a G/U-rich sequence element downstream. Any method known to the skilled artisan can be used to detect and  
10       quantify the activity of a 3' end pre-mRNA endonuclease.

An assay for the activity of a 3' end pre-mRNA endonuclease can be performed in a cell, using a cell extract or *in vitro* using a purified mammalian 3' end pre-mRNA endonuclease complex. For a description of 3' end pre-mRNA endonuclease complexes see section 4.2.2.

If the assay is performed in a cell, the cell expresses all components required for the  
15       activity of the 3' end pre-mRNA endonuclease. In certain, more specific embodiments, the cell is a mammalian cell, *e.g.*, a human cell, that endogenously expresses all components of a 3' end pre-mRNA endonuclease complex. In other embodiments, the cell has been modified to recombinantly express one or more components of the 3' end pre-mRNA endonuclease complex. Further, the detectably labeled substrate of the 3' end pre-mRNA endonuclease reaction can be  
20       microinjected or transfected (permanently or transiently) into the cell by any method known to the skilled artisan. If a reporter gene construct is used as a substrate, the substrate can be microinjected or transfected (permanently or transiently) into the cell or the cell can be modified such that the reporter gene is integrated into the genome of the cell.

In certain embodiments, a 3' end pre-mRNA reporter gene construct is used as substrate  
25       to detect and/or quantify the activity of a 3' end pre-mRNA endonuclease (see Fig. 19). In certain embodiments, a 3' end pre-mRNA reporter gene construct encodes two open reading frames (ORF), the upstream and the downstream ORF, wherein the two ORFs are separated by a cleavage and polyadenylation signal and the 3' located ORF is preceded by an internal ribosome entry site (IRES). For an example of a 3' end pre-mRNA reporter gene construct, see Figure 18.  
30       If the cleavage takes place at the cleavage and polyadenylation site, the downstream reporter gene at the 3' end of the construct is not transcribed. Thus, the more active the 3' end pre-mRNA endonuclease is the less of the downstream reporter gene is expressed. The less active, *i.e.*, in the presence of an inhibitor, the 3' end pre-mRNA endonuclease is the more RNA that

includes the downstream reporter gene will be transcribed. The downstream reporter gene can then be translated via the IRES. Any IRES can be used with the methods of the invention. In a specific embodiment, the IRES is an IRES of the Hepatitis C virus (HCV). The substrate can be generated by any recombinant DNA technology known to the skilled artisan.

5 In certain embodiments, the ratio between the upstream reporter gene and the downstream reporter gene of the 3' end pre-mRNA reporter gene construct is the read-out. Thus, an increase in 3' end pre-mRNA cleavage will result in an increase of the upstream reporter gene:downstream reporter gene ratio. A decrease in 3' end pre-mRNA cleavage will result in a decrease of the upstream reporter gene:downstream reporter gene ratio.

10

#### 4.5.4.1.4 Vectors

The nucleotide sequence coding for a reporter gene and the nucleotide sequence coding for a tRNA intron, the 3' end pre-mRNA cleavage site, the pre-tRNA cleavage site or the rRNA  
15 cleavage site can be inserted into an appropriate expression vector, *i.e.*, a vector which contains the necessary elements for the transcription and translation of the inserted protein-coding sequence. The necessary transcriptional and translational signals can also be supplied by the reporter gene. A variety of host-vector systems may be utilized to express the reporter gene. These include, but are not limited to, mammalian cell systems infected with virus (*e.g.*, vaccinia  
20 virus, adenovirus, *etc.*); insect cell systems infected with virus (*e.g.*, baculovirus); microorganisms such as yeast containing yeast vectors, or bacteria transformed with bacteriophage, DNA, plasmid DNA, or cosmid DNA; and stable cell lines generated by transformation using a selectable marker. The expression elements of vectors vary in their strengths and specificities. Depending on the host-vector system utilized, any one of a number  
25 of suitable transcription and translation elements may be used.

Any of the methods previously described for the insertion of DNA fragments into a vector may be used to construct expression vectors containing a chimeric nucleic acid consisting of appropriate transcriptional/translational control signals and the protein coding sequences. These methods may include *in vitro* recombinant DNA and synthetic techniques and *in vivo*  
30 recombinants (genetic recombination). Expression of the reporter gene construct may be regulated by a second nucleic acid sequence so that the reporter gene is expressed in a host transformed with the recombinant DNA molecule. For example, expression of a reporter gene

construct may be controlled by any promoter/enhancer element known in the art, such as a constitutive promoter, a tissue-specific promoter, or an inducible promoter. Specific examples of promoters which may be used to control gene expression include, but are not limited to, the SV40 early promoter region (Bernoist & Chambon, 1981, *Nature* 290:304-310), the promoter  
5 contained in the 3' long terminal repeat of Rous sarcoma virus (Yamamoto et al., 1980, *Cell* 22:787-797), the herpes thymidine kinase promoter (Wagner et al., 1981, *Proc. Natl. Acad. Sci. U.S.A.* 78:1441-1445), the regulatory sequences of the metallothionein gene (Brinster et al., 1982, *Nature* 296:39-42); prokaryotic expression vectors such as the  $\beta$ -lactamase promoter (Villa-Kamaroff et al., 1978, *Proc. Natl. Acad. Sci. U.S.A.* 75:3727-3731), or the *tac* promoter  
10 (DeBoer et al., 1983, *Proc. Natl. Acad. Sci. U.S.A.* 80:21-25); see also "Useful proteins from recombinant bacteria" in *Scientific American*, 1980, 242:74-94; plant expression vectors comprising the nopaline synthetase promoter region (Herrera-Estrella et al., *Nature* 303:209-213) or the cauliflower mosaic virus 35S RNA promoter (Gardner, et al., 1981, *Nucl. Acids Res.* 9:2871), and the promoter of the photosynthetic enzyme ribulose biphosphate carboxylase  
15 (Herrera-Estrella et al., 1984, *Nature* 310:115-120); promoter elements from yeast or other fungi such as the Gal 4 promoter, the ADC (alcohol dehydrogenase) promoter, PGK (phosphoglycerol kinase) promoter, alkaline phosphatase promoter, and the following animal transcriptional control regions, which exhibit tissue specificity and have been utilized in transgenic animals: elastase I gene control region which is active in pancreatic acinar cells (Swift et al., 1984, *Cell*  
20 38:639-646; Ornitz et al., 1986, *Cold Spring Harbor Symp. Quant. Biol.* 50:399-409; MacDonald, 1987, *Hepatology* 7:425-515); insulin gene control region which is active in pancreatic beta cells (Hanahan, 1985, *Nature* 315:115-122), immunoglobulin gene control region which is active in lymphoid cells (Grosschedl et al., 1984, *Cell* 38:647-658; Adames et al., 1985, *Nature* 318:533-538; Alexander et al., 1987, *Mol. Cell. Biol.* 7:1436-1444), mouse  
25 mammary tumor virus control region which is active in testicular, breast, lymphoid and mast cells (Leder et al., 1986, *Cell* 45:485-495), albumin gene control region which is active in liver (Pinkert et al., 1987, *Genes and Devel.* 1:268-276), alpha-fetoprotein gene control region which is active in liver (Krumlauf et al., 1985, *Mol. Cell. Biol.* 5:1639-1648; Hammer et al., 1987, *Science* 235:53-58; alpha 1-antitrypsin gene control region which is active in the liver (Kelsey et  
30 al., 1987, *Genes and Devel.* 1:161-171), beta-globin gene control region which is active in myeloid cells (Mogam et al., 1985, *Nature* 315:338-340; Kollias et al., 1986, *Cell* 46:89-94; myelin basic protein gene control region which is active in oligodendrocyte cells in the brain (Readhead et al., 1987, *Cell* 48:703-712); myosin light chain-2 gene control region which is



active in skeletal muscle (Sani, 1985, Nature 314:283-286), and gonadotropic releasing hormone gene control region which is active in the hypothalamus (Mason et al., 1986, Science 234:1372-1378).

5 In a specific embodiment, a vector is used that comprises a promoter operably linked to a reporter gene, one or more origins of replication, and, optionally, one or more selectable markers (*e.g.*, an antibiotic resistance gene). In a preferred embodiment, the vectors are CMV vectors, T7 vectors, lac vectors, pCEP4 vectors, 5.0/F vectors, or vectors with a tetracycline-regulated promoter (*e.g.*, pcDNA<sup>TM</sup>5/FRT/TO from Invitrogen

10 Expression vectors containing the reporter gene construct of the present invention can be identified by three general approaches: (a) nucleic acid hybridization, (b) presence or absence of “marker” nucleic acid functions, (c) expression of inserted sequences, and (d) sequencing. In the first approach, the presence of the reporter gene inserted in an expression vector can be detected by nucleic acid hybridization using probes comprising sequences that are homologous to the inserted reporter gene. In the second approach, the recombinant vector/host system can be  
15 identified and selected based upon the presence or absence of certain “marker” nucleic acid functions (*e.g.*, thymidine kinase activity, resistance to antibiotics, transformation phenotype, occlusion body formation in baculovirus, *etc.*) caused by the insertion of the nucleic acid of interest, *i.e.*, the reporter gene construct, in the vector. For example, if the nucleic acid of interest is inserted within the marker nucleic acid sequence of the vector, recombinants  
20 containing the insert can be identified by the absence of the marker nucleic acid function. In the third approach, recombinant expression vectors can be identified by assaying the reporter gene product expressed by the recombinant. Such assays can be based, for example, on the physical or functional properties of the particular reporter gene.

25 In a preferred embodiment, the reporter gene constructs are cloned into stable cell line expression vectors. In a preferred embodiment, the stable cell line expression vector contains a site specific genomic integration site. In another preferred embodiment, the reporter gene construct is cloned into an episomal mammalian expression vector.

#### 4.5.4.1.5 Transfection

30 Once a vector encoding the appropriate gene has been synthesized, a host cell is transformed or transfected with the vector of interest. The use of stable transformants is preferred. In a preferred embodiment, the host cell is a mammalian cell. In a more preferred embodiment, the host cell is a human cell. In another embodiment, the host cells are primary

cells isolated from a tissue or other biological sample of interest. Host cells that can be used in the methods of the present invention include, but are not limited to, hybridomas, pre-B cells, 293 cells, 293T cells, HeLa cells, HepG2 cells, K562 cells, 3T3 cells. In another preferred embodiment, the host cells are immortalized cell lines derived from a source, *e.g.*, a tissue.

- 5 Other host cells that can be used in the present invention include, but are not limited to, virally-infected cells.

Transformation may be by any known method for introducing polynucleotides into a host cell, including, for example packaging the polynucleotide in a virus and transducing a host cell with the virus, and by direct uptake of the polynucleotide. The transformation procedure  
10 used depends upon the host to be transformed. Mammalian transformations (*i.e.*, transfections) by direct uptake may be conducted using the calcium phosphate precipitation method of Graham & Van der Eb, 1978, *Virology* 52:546, or the various known modifications thereof. Other methods for introducing recombinant polynucleotides into cells, particularly into mammalian cells, include dextran-mediated transfection, calcium phosphate mediated transfection, polybrene  
15 mediated transfection, protoplast fusion, electroporation, encapsulation of the polynucleotide(s) in liposomes, and direct microinjection of the polynucleotides into nuclei. Such methods are well-known to one of skill in the art.

In a preferred embodiment, stable cell lines containing the constructs of interest are generated for high throughput screening. Such stable cell lines may be generated by  
20 introducing a reporter gene construct comprising a selectable marker, allowing the cells to grow for 1-2 days in an enriched medium, and then growing the cells on a selective medium. The selectable marker in the recombinant plasmid confers resistance to the selection and allows cells to stably integrate the plasmid into their chromosomes and grow to form foci which in turn can be cloned and expanded into cell lines.

25 A number of selection systems may be used, including but not limited to the herpes simplex virus thymidine kinase (Wigler, et al., 1977, *Cell* 11:223), hypoxanthine-guanine phosphoribosyltransferase (Szybalska & Szybalski, 1962, *Proc. Natl. Acad. Sci. USA* 48:2026), and adenine phosphoribosyltransferase (Lowy, et al., 1980, *Cell* 22:817) genes can be employed in tk-, hgp<sup>r</sup>t- or ap<sup>r</sup>t- cells, respectively. Also, anti-metabolite resistance can be used as the  
30 basis of selection for dhfr, which confers resistance to methotrexate (Wigler, et al., 1980, *Natl. Acad. Sci. USA* 77:3567; O'Hare, et al., 1981, *Proc. Natl. Acad. Sci. USA* 78:1527); gpt, which confers resistance to mycophenolic acid (Mulligan & Berg, 1981, *Proc. Natl. Acad. Sci. USA* 78:2072); neo, which confers resistance to the aminoglycoside G-418 (Colberre-Garapin, et al.,

1981, J. Mol. Biol. 150:1); and hygro, which confers resistance to hygromycin (Santerre, et al., 1984, Gene 30:147) genes.

#### 4.5.4.1.6 Cell-Free Extracts

The invention provides for the translation of the reporter gene constructs in a cell-free system. Techniques for practicing this specific aspect of this invention will employ, unless otherwise indicated, conventional techniques of molecular biology, microbiology, and recombinant DNA manipulation and production, which are routinely practiced by one of skill in the art. See, e.g., Sambrook, 1989, Molecular Cloning, A Laboratory Manual, Second Edition; DNA Cloning, Volumes I and II (Glover, Ed. 1985); and Transcription and Translation (Hames & Higgins, Eds. 1984).

Any technique well-known to one of skill in the art may be used to generate cell-free extracts for translation *in vitro*. For example, the cell-free extracts for *in vitro* translation reactions can be generated by centrifuging cells and clarifying the supernatant. In particular, a cell extract utilized in accordance with the invention may be an S1 extract (*i.e.*, the supernatant from a 1,000 x g spin) to an S500 extract (*i.e.*, the supernatant from a 500,000 x g spin), preferably an S10 extract (*i.e.*, the supernatant from a 10,000 x g spin) to an S250 extract (*i.e.*, the supernatant from a 250,000 x g spin). In a specific embodiment, a cell extract utilized in accordance with the invention is an S50 extract (*i.e.*, the supernatant from a 50,000 x g spin) to an S100 extract (*i.e.*, the supernatant from a 100,000 x g spin).

The cell-free translation extract may be isolated from cells of any species origin. For example, the cell-free translation extract may be isolated from human cells, cultured mouse cells, cultured rat cells, Chinese hamster ovary (CHO) cells, *Xenopus* oocytes, rabbit reticulocytes, wheat germ, or rye embryo (see, e.g., Krieg & Melton, 1984, Nature 308:203 and Dignam *et al.*, 1990 Methods Enzymol. 182:194-203). Alternatively, the cell-free translation extract, e.g., rabbit reticulocyte lysates and wheat germ extract, can be purchased from, e.g., Promega, (Madison, WI). In a preferred embodiment, the cell-free extract is an extract isolated from human cells. In a more preferred embodiment, the human cells are HeLa cells.

#### 4.5.5 Reporter Gene-Based Assays

##### 4.5.5.1 Cell-Based Assays

After a vector containing the reporter gene construct is transformed or transfected into a host cell and a compound library is synthesized or purchased or both, the cells are used to screen

the library to identify compounds that modulate the activity of a mammalian tRNA splicing endonuclease, a mammalian 3' end pre-mRNA endonuclease, pre-tRNA cleavage activity, or rRNA cleavage activity.

5 An assay for the activity of a tRNA endonuclease can be performed in a cell, using a cell extract or *in vitro* using a purified mammalian tRNA endonuclease complex. If the assay is performed in a cell, the cell expresses all components required for the activity of the tRNA endonuclease. In certain, more specific embodiments, the cell is a mammalian cell, *e.g.*, a human cell, that endogenously expresses all components of a tRNA endonuclease complex. In other embodiments, the cell has been modified to recombinantly express one or more  
10 components of the tRNA endonuclease complex. Further, the detectably labeled substrate of the tRNA endonuclease reaction can be microinjected or transfected (permanently or transiently) into the cell by any method known to the skilled artisan. If a reporter gene construct is used as a substrate, the substrate can be microinjected or transfected (permanently or transiently) into the cell or the cell can be modified such that the reporter gene is integrated into the genome of the  
15 cell.

The reporter gene-based assays for tRNA splicing endonuclease activity may be conducted by contacting a compound or a member of a library of compounds with a cell genetically engineered to contain a reporter gene construct comprising a reporter gene and a tRNA intron within the open reading frame of the reporter gene, or within the 5' untranslated  
20 region, 3' untranslated region or both the 5' and 3' untranslated regions of the reporter gene construct, or within a mRNA splice site of the reporter gene; and measuring the expression of said reporter gene if pre-tRNA splicing endonuclease activity is to be assayed.

The alteration in reporter gene expression relative to a previously determined reference range, the absence of the compound or a control in such reporter-gene based assays indicates  
25 that a particular compound modulates the activity of a tRNA splicing endonuclease. A decrease in reporter gene expression relative to a previously determined reference range, the absence of the compound or a control in such reporter-gene based assays indicates that a particular compound reduces or inhibits the activity of a tRNA splicing endonuclease (*e.g.*, the recognition or cleavage of a tRNA intron). An increase in reporter gene expression relative to a previously  
30 determined reference range, the absence of the compound or a control in such reporter-gene based assays indicates that a particular compound enhances the activity of a tRNA splicing endonuclease. In a preferred embodiment, a negative control (*e.g.*, PBS or another agent that is known to have no effect on the expression of the reporter gene) and a positive control (*e.g.*, an

agent that is known to have an effect on the expression of the reporter gene, preferably an agent that effects the activity of a human tRNA splicing endonuclease) are included in the cell-based assays described herein. In a particular embodiment, the pre-tRNA splicing endonuclease is a human pre-tRNA splicing endonuclease complex.

5           An assay for the activity of a 3' end pre-mRNA endonuclease can be performed in a cell, using a cell extract or *in vitro* using a purified mammalian 3' end pre-mRNA endonuclease complex. If the assay is performed in a cell, the cell expresses all components required for the activity of the 3' end pre-mRNA endonuclease. In certain, more specific embodiments, the cell is a mammalian cell, *e.g.*, a human cell, that endogenously expresses all components of a 3' end  
10   pre-mRNA endonuclease complex. In other embodiments, the cell has been modified to recombinantly express one or more components of the 3' end pre-mRNA endonuclease complex. Further, the detectably labeled substrate of the 3' end pre-mRNA endonuclease reaction can be microinjected or transfected (permanently or transiently) into the cell by any method known to the skilled artisan. If a reporter gene construct is used as a substrate, the substrate can be  
15   microinjected or transfected (permanently or transiently) into the cell or the cell can be modified such that the reporter gene is integrated into the genome of the cell.

          The reporter gene based assays for 3' end pre-mRNA endonuclease activity may be conducted by contacting a compound or a member of a library of compounds with a cell genetically engineered to contain a reporter gene construct comprising a reporter gene and a 3'  
20   end pre-mRNA cleavage site. In a particular embodiment, the 3' end pre-mRNA endonuclease is a human 3' end pre-mRNA endonuclease complex.

          In certain embodiments, a 3' end pre-mRNA reporter gene construct encodes two open reading frames (ORF), the upstream and the downstream ORF, wherein the two ORFs are separated by a cleavage and polyadenylation signal and the 3' located ORF is preceded by an  
25   internal ribosome entry site (IRES). For an example of a 3' end pre-mRNA reporter gene construct, see Figure 18. If the cleavage takes place at the cleavage and polyadenylation site, the downstream reporter gene at the 3' end of the construct is not transcribed. Thus, the more active the 3' end pre-mRNA endonuclease is the less of the downstream reporter gene is expressed. The less active, *i.e.*, in the presence of an inhibitor, the 3' end pre-mRNA endonuclease is the  
30   more RNA that includes the downstream reporter gene will be transcribed. The downstream reporter gene can then be translated via the IRES.

          In certain embodiments, the ratio between the upstream reporter gene and the downstream reporter gene of the 3' end pre-mRNA reporter gene construct is the read-out.

Thus, an increase in 3' end pre-mRNA cleavage will result in an increase of the upstream reporter gene:downstream reporter gene ratio. A decrease in 3' end pre-mRNA cleavage will result in a decrease of the upstream reporter gene:downstream reporter gene ratio.

5 The step of contacting a compound or a member of a library of compounds with a cell genetically engineered to contain a reporter gene construct may be conducted under physiologic conditions. In specific embodiment, a compound or a member of a library of compounds is added to the cells in the presence of an aqueous solution. In accordance with this embodiment, the aqueous solution may comprise a buffer and a combination of salts, preferably approximating or mimicking physiologic conditions. Alternatively, the aqueous solution may  
10 comprise a buffer, a combination of salts, and a detergent or a surfactant. Examples of salts which may be used in the aqueous solution include, but not limited to, KCl, NaCl, and/or MgCl<sub>2</sub>. The optimal concentration of each salt used in the aqueous solution is dependent on the cells and compounds used and can be determined using routine experimentation. The step of contacting a compound or a member of a library of compounds with a human cell genetically engineered to  
15 contain the reporter gene construct may be performed for at least 0.2 hours, 0.25 hours, 0.5 hours, 1 hour, 2 hours, 3 hours, 4 hours, 5 hours, 6 hours, 8 hours, 10 hours, 12 hours, 18 hours, or at least 1 day.

In one embodiment, the invention provides a method for identifying a compound that modulates tRNA splicing endonuclease activity or 3' end pre-mRNA endonuclease activity,  
20 wherein the method comprises: (a) expressing a nucleic acid comprising a reporter gene in a cell, wherein the reporter gene comprises a tRNA intron or a 3' end pre-mRNA cleavage site; (b) contacting said cell with a compound or a member of a library of compounds; and (c) detecting the expression of said reporter gene, wherein a compound that modulates tRNA splicing endonuclease activity is identified if the expression of said reporter gene in the presence of a  
25 compound is altered relative to a previously determined reference range or the expression of said reporter gene in the absence of the compound or the presence of a control. In another embodiment, the invention provides a method for identifying a compound that modulates tRNA splicing endonuclease activity or pre-tRNA splicing endonuclease activity, said method comprising: (a) contacting a member of a library of compounds with a cell containing a nucleic  
30 acid comprising a reporter gene, wherein the reporter gene comprises a tRNA intron or a 3' end pre-mRNA endonuclease cleavage site; and (b) detecting the expression of said reporter gene, wherein a compound that modulates tRNA splicing endonuclease activity or 3' end pre-mRNA endonuclease activity is identified if the expression of said reporter gene in the presence of a

compound is altered relative to a previously determined reference range the expression of said reporter gene in the absence of said compound or the presence of a control.

The expression of a reporter gene and/or activity of the protein encoded by the reporter gene in the cell-based reporter-gene assays may be detected by any technique well-known to one of skill in the art. The expression of a reporter gene can be readily detected, *e.g.*, by quantifying the protein and/or RNA encoded by said gene. Many methods standard in the art can be thus employed, including, but not limited to, immunoassays to detect and/or visualize gene expression (*e.g.*, Western blot, immunoprecipitation followed by sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE), immunocytochemistry, etc) and/or hybridization assays to detect gene expression by detecting and/or visualizing respectively mRNA encoding a gene (*e.g.*, Northern assays, dot blots, *in situ* hybridization, etc), etc. Such assays are routine and well known in the art (see, *e.g.*, Ausubel et al, eds, 1994, Current Protocols in Molecular Biology, Vol. 1, John Wiley & Sons, Inc., New York, which is incorporated by reference herein in its entirety). Exemplary immunoassays are described briefly below (but are not intended by way of limitation).

Immunoprecipitation protocols generally comprise lysing a population of cells in a lysis buffer such as RIPA buffer (1% NP-40 or Triton X-100, 1% sodium deoxycholate, 0.1% SDS, 0.15 M NaCl, 0.01 M sodium phosphate at pH 7.2, 1% Trasylol) supplemented with protein phosphatase and/or protease inhibitors (*e.g.*, EDTA, PMSF, aprotinin, sodium vanadate), adding the antibody which recognizes the antigen to the cell lysate, incubating for a period of time (*e.g.*, 1 to 4 hours) at 40° C, adding protein A and/or protein G sepharose beads to the cell lysate, incubating for about an hour or more at 40° C, washing the beads in lysis buffer and resuspending the beads in SDS/sample buffer. The ability of the antibody to immunoprecipitate a particular antigen can be assessed by, *e.g.*, western blot analysis. One of skill in the art would be knowledgeable as to the parameters that can be modified to increase the binding of the antibody to an antigen and decrease the background (*e.g.*, pre-clearing the cell lysate with sepharose beads). For further discussion regarding immunoprecipitation protocols see, *e.g.*, Ausubel et al, eds, 1994, Current Protocols in Molecular Biology, Vol. 1, John Wiley & Sons, Inc., New York at 10.16.1.

Western blot analysis generally comprises preparing protein samples, electrophoresis of the protein samples in a polyacrylamide gel (*e.g.*, 8%- 20% SDS-PAGE depending on the molecular weight of the antigen), transferring the protein sample from the polyacrylamide gel to a membrane such as nitrocellulose, PVDF or nylon, blocking the membrane in blocking solution

(*e.g.*, PBS with 3% BSA or non-fat milk), washing the membrane in washing buffer (*e.g.*, PBS-Tween 20), blocking the membrane with primary antibody (the antibody which recognizes the antigen) diluted in blocking buffer, washing the membrane in washing buffer, blocking the membrane with a secondary antibody (which recognizes the primary antibody, *e.g.*, an anti-  
5 human antibody) conjugated to an enzymatic substrate (*e.g.*, horseradish peroxidase or alkaline phosphatase) or radioactive molecule (*e.g.*,  $^{32}\text{P}$  or  $^{125}\text{I}$ ) diluted in blocking buffer, washing the membrane in wash buffer, and detecting the presence of the antigen. One of skill in the art would be knowledgeable as to the parameters that can be modified to increase the signal detected and to reduce the background noise. For further discussion regarding western blot  
10 protocols see, *e.g.*, Ausubel et al, eds, 1994, Current Protocols in Molecular Biology, Vol. 1, John Wiley & Sons, Inc., New York at 10.8.1.

ELISAs comprise preparing antigen, coating the well of a 96 well microtiter plate with the antigen, adding a primary antibody (which recognizes the antigen) conjugated to a detectable compound such as an enzymatic substrate (*e.g.*, horseradish peroxidase or alkaline phosphatase)  
15 to the well and incubating for a period of time, and detecting the presence of the antigen. In ELISAs the antibody of interest does not have to be conjugated to a detectable compound; instead, a second antibody (which recognizes the primary antibody) conjugated to a detectable compound may be added to the well. Further, instead of coating the well with the antigen, the antibody may be coated to the well. In this case, a second antibody conjugated to a detectable  
20 compound may be added following the addition of the antigen of interest to the coated well. One of skill in the art would be knowledgeable as to the parameters that can be modified to increase the signal detected as well as other variations of ELISAs known in the art. For further discussion regarding ELISAs see, *e.g.*, Ausubel et al, eds, 1994, Current Protocols in Molecular Biology, Vol. 1, John Wiley & Sons, Inc., New York at 11.2.1.

25 Methods for detecting the activity of a protein encoded by a reporter gene will vary with the reporter gene used. Assays for the various reporter genes are well-known to one of skill in the art. For example, as described in Section 5.2.1., luciferase, beta-galactosidase ("beta-gal"), beta-glucuronidase ("GUS"), beta-lactamase, chloramphenicol acetyltransferase ("CAT"), and alkaline phosphatase ("AP") are enzymes that can be analyzed in the presence of a substrate and  
30 could be amenable to high throughput screening. For example, the reaction products of luciferase, beta-galactosidase ("beta-gal"), and alkaline phosphatase ("AP") are assayed by changes in light imaging (*e.g.*, luciferase), spectrophotometric absorbance (*e.g.*, beta-gal), or fluorescence (*e.g.*, AP). Assays for changes in light output, absorbance, and/or fluorescence are



easily adapted for high throughput screening. For example, beta-gal activity can be measured with a microplate reader. Green fluorescent protein ("GFP") activity can be measured by changes in fluorescence. For example, in the case of mutant GFPs that fluoresce at 488 nm, standard fluorescence activated cell sorting ("FACS") equipment can be used to separate cells based upon GFP activity.

Alterations in the expression of a reporter gene may be determined by comparing the level of expression of the reporter gene to a negative control (*e.g.*, PBS or another agent that is known to have no effect on the expression of the reporter gene) and optionally, a positive control (*e.g.*, an agent that is known to have an effect on the expression of the reporter gene, preferably an agent that effects the activity of a human tRNA splicing endonuclease). Alternatively, alterations in the expression of a reporter gene may be determined by comparing the level of expression of the reporter gene to a previously determined reference range.

#### 4.5.5.2 Cell-Free Assays

After a vector containing the reporter gene construct is produced, a cell-free translation extract is generated or purchased, and a compound library is synthesized or purchased or both, the cell-free translation extract and nucleic acid are used to screen the library to identify compounds that modulate the activity of tRNA splicing endonuclease or 3' end pre-mRNA endonuclease. The reporter gene-based assays may be conducted in a cell-free manner by contacting a compound with a cell-free extract and a reporter gene construct comprising the reporter gene construct (which, depending on whether 3' end pre-mRNA endonuclease activity or pre-tRNA splicing endonuclease activity is to be assayed, comprises a reporter gene and a pre-tRNA splice site or a 3' end pre-mRNA endonuclease site, respectively), and measuring the expression of said reporter gene. The alteration in reporter gene expression relative to a previously determined reference range, the absence of the compound or a control in such reporter-gene based assays indicates that a particular compound modulates the activity of a tRNA splicing endonuclease or a pre-tRNA splicing endonuclease.

The activity of a compound in the cell-free extract can be determined by assaying the activity of a reporter protein encoded by a reporter gene, or alternatively, by quantifying the expression of the reporter gene by, for example, labeling the *in vitro* translated protein (*e.g.*, with <sup>35</sup>S-labeled methionine), northern blot analysis, RT-PCR or by immunological methods, such as western blot analysis or immunoprecipitation. Such methods are well-known to one of skill in the art.

#### 4.5.6 FRET Assays

Fluorescence resonance energy transfer ("FRET") can be used to detect alterations in the activity of a tRNA splicing endonuclease or a 3' end pre-mRNA endonuclease complex. In the FRET assays described herein, the subunits of a complex of the invention or a substrate for a tRNA splicing endonuclease or a 3' end pre-mRNA endonuclease complex may be labeled with fluorophores.

In order to obtain FRET between the fluorescent donor moiety and the fluorescent acceptor moiety or a quencher, the two moieties have to be in spatial proximity with each other.

Thus, in certain embodiments, a substrate or subunits of a complex of the invention are labeled such that the fluorescent donor moiety and the fluorescent acceptor moiety or a quencher are at most 0.5 nm, at most 1 nm, at most 5 nm, at most 10 nm, at most 20 nm, at most 30 nm, at most 40 nm, at most 50 nm or at most 100 nm apart from each other.

Any nucleotide sequence recognized and excised by a human tRNA splicing endonuclease may be utilized as a substrate for a human tRNA splicing endonuclease in a FRET assay described herein. For example, a nucleotide sequence comprising a bulge-helix-bulge structure or a mature domain of a precursor tRNA may be utilized as a substrate for a human tRNA splicing endonuclease in a FRET assay described herein. A nucleotide sequence recognized and excised by a human tRNA splicing endonuclease may comprise 10 nucleotides, 15 nucleotides, 20 nucleotides, 25 nucleotides, 30 nucleotides, 40 nucleotides, 45 nucleotides, 50 nucleotides, 55 nucleotides, 60 nucleotides, 65 nucleotides, 75 nucleotides, 100 nucleotides, 125 nucleotides, 150 nucleotides, or more. In a specific embodiment, the substrates for a tRNA splicing endonuclease utilized in the FRET assays described herein comprise a tRNA intron. The substrate may comprise a bulge-helix-bulge conformation. In a preferred embodiment, the substrate comprises a tRNA mature domain that contains an intron.

In certain embodiments, the substrates depicted in Figure 1 are used in the FRET assays. In particular, the hybridized tRNA substrate and circularly permuted tRNA substrate depicted in Figures 1B and 1C, respectively, are used in the FRET assays. The free 5' and 3' ends of the intron of the hybridized tRNA substrate (Figure 1B) or the free 5' and 3' ends of the intron of circularly permuted tRNA substrate (Figure 1C) may be labeled with a fluorophore such that the close spatial proximity of the fluorophore on the 5' end with the fluorophore on the 3' end results in fluorescence resonance energy transfer. Cleavage of the substrate will then result in a

spatial separation of the labeled 5' end from the labeled 3' end and thus, in reduced fluorescence resonance energy transfer. Thus, the skilled artisan can measure FRET and determine the concentration of cleaved versus uncleaved substrate. The concentration of uncleaved substrate decreases as FRET declines.

5           Alternatively, the 3' end or the 5' end is labeled with a fluorophore and the other end, *i.e.*, the 5' end or the 3' end, respectively, is labeled with a quencher of the fluorophore. Upon cleavage of the intron by tRNA splicing endonuclease, the quencher and the fluorophore are separated from each other resulting in a measurable change in fluorescence. The fluorescence signal increases as the cleavage reaction proceeds.

10           In certain embodiments, a substrate of 3' end pre-mRNA endonuclease complex is labeled such that its cleavage would result in loss of FRET, *i.e.*, one end is labeled with the donor fluorophore and the other end is labeled with an acceptor fluorophore. Alternatively, a substrate of 3' end pre-mRNA endonuclease complex is labeled such that its cleavage would result in emergence of a signal. In this embodiment, one end of the substrate is labeled with a  
15           fluorophore and the other end is labeled with a quencher.

          In accordance with the invention, a substrate can be labeled with a single pair of fluorescent donor and acceptor moieties. A substrate can be labeled with different pairs of fluorescent donor moieties and fluorescent acceptor moieties. For example, two, three, four, five or more pairs of fluorescent donor moieties and fluorescent acceptor moieties can be used.  
20           In this situation, preferably, at least one of the pairs comprise a fluorescent acceptor moiety that has a different emission spectrum from the fluorescent acceptor moiety of at least one of the other pairs. Alternatively, when at least three pairs are used, the fluorescent acceptor moiety of the first pair, second pair and third pair has a different emission spectrum than the fluorescent acceptor moiety of the other two. Methods for labeling the substrate with a fluorescent acceptor  
25           moiety, a fluorescent donor moiety and/or quencher are well-known in the art (see, *e.g.*, U.S. Patent Nos. 6,472,156, 6,451,543, 6,348,322, 6,342,379, 6,323,039, 6,297,018, 6,291,201, 6,280,981, 5,843,658, and 5,439,797, the disclosures of which are incorporated by reference in their entirety). The labeled substrate can be microinjected or transfected into human cells (preferably, mammalian cells and more preferably, human cells) utilizing techniques well-  
30           known to one of skill in the art (see, *e.g.*, Adams et al., 1991, Nature 349:694-697).

#### 4.5.6.1    Cell-Based Assays with a Labeled Substrate

The FRET cell-based assays may be conducted by microinjecting or transfecting (*e.g.*, using liposomes or electroporation) a substrate for a tRNA splicing endonuclease or a substrate for a 3' end pre-mRNA endonuclease into a cell and contacting the cell with a compound, wherein the substrate is labeled such that its cleavage by either 3' end pre-mRNA endonuclease complex or the pre-tRNA splicing endonuclease complex would result in the loss of FRET or the emergence of fluorescence, *e.g.*, fluorescence microscopy or a fluorescence emission detector such as a Viewlux or Analyst.

In certain embodiments, a substrate is labeled with a fluorophore and a quencher in spatial proximity such that the quencher reduces or eliminates the signal emitted from the fluorophore. Upon cleavage of the labeled substrate the quencher and the fluorophore are no longer in spatial proximity and the signal emitted from the fluorophore increases or emerges. The labeled substrate is then microinjected or transfected into a cell for assaying the effect of a compound on 3' end pre-mRNA endonuclease activity or pre-tRNA endonuclease activity. In other embodiments, a substrate can be labeled with two different fluorophores. The FRET cell-based assays may be conducted by microinjecting or transfecting a substrate for a human tRNA splicing endonuclease into a cell and contacting the cell with a compound, wherein the substrate is labeled at the 5' end with a fluorescent donor moiety and labeled at the 3' end with a fluorescent acceptor moiety, or, alternatively, the substrate is labeled at the 5' end with a fluorescent acceptor moiety and labeled at the 3' end with a fluorescent donor moiety, and measuring the fluorescence of the substrate by, *e.g.*, fluorescence microscopy or a fluorescence emission detector such as a Viewlux or Analyst. The endogenous tRNA splicing endonuclease will cleave the substrate and result in the production of a detectable fluorescent signal by the fluorescent donor moiety and fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety. A compound that inhibits or reduces the activity of the endogenous tRNA splicing endonuclease will inhibit or reduce cleavage of the substrate and thus, increase the fluorescence emission of the fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety relative to a negative control (*e.g.*, PBS). A compound that enhances the activity of the endogenous tRNA splicing endonuclease will enhance the cleavage of the substrate and thus, reduce the fluorescence emission of the fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety relative to a negative control (*e.g.*, PBS). In a preferred embodiment, a negative control (*e.g.*, PBS or another agent that is known to have no effect on the cleavage of the substrate) and a positive control (*e.g.*, an agent that is known to have an effect on the cleavage of the substrate) are included in the FRET cell-based assays described

herein.

Alternatively, the FRET cell-based assays may be conducted by microinjecting or transfecting a substrate for a human tRNA splicing endonuclease into a cell and contacting the cell with a compound, wherein the substrate is labeled at the 5' end with a fluorescent donor moiety and labeled at the 3' end with a fluorescent acceptor moiety, or, alternatively, the substrate is labeled at the 5' end with a fluorescent acceptor moiety and labeled at the 3' end with a fluorescent donor moiety, and measuring the fluorescence of the substrate by, *e.g.*, fluorescence microscopy or a fluorescence emission detector such as a Viewlux or Analyst. The endogenous tRNA splicing endonuclease will cleave the substrate and result in the production of a detectable fluorescent signal by the fluorescent donor moiety and fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety. A compound that inhibits or reduces the activity of the endogenous tRNA splicing endonuclease will inhibit or reduce cleavage of the substrate and thus, increase the fluorescence emission of the fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety relative to a negative control (*e.g.*, PBS). A compound that enhances the activity of the endogenous tRNA splicing endonuclease will enhance the cleavage of the substrate and thus, reduce the fluorescence emission of the fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety relative to a negative control (*e.g.*, PBS). In a preferred embodiment, a negative control (*e.g.*, PBS or another agent that is known to have no effect on the cleavage of the substrate) and a positive control (*e.g.*, an agent that is known to have an effect on the cleavage of the substrate) are included in the FRET cell-based assays described herein.

The assay can be conducted in any buffer system that provides conditions conducive to the tRNA endonuclease reaction. Such buffer systems are well known to the skilled artisan. In a specific embodiment, the buffer is the medium in which the cell culture is kept. Care should be taken that Magnesium ions are present in the medium.

In certain embodiments, the assay is conducted for at least 0.2 hours, 0.25 hours, 0.5 hours, 1 hour, 2 hours, 3 hours, 4 hours, 5 hours, 6 hours, 8 hours, 10 hours, 12 hours, 18 hours, or at least 1 day.

In a specific embodiment, the invention provides a method of identifying an antiproliferative compound that inhibits or reduces human tRNA splicing endonuclease activity, said method comprising: (a) microinjecting or transfecting a substrate of a tRNA splicing endonuclease into a human cell, wherein the substrate is labeled at the 5' end with a fluorophore and labeled at the 3' end with a quencher, or alternatively, the substrate is labeled at the 5' end

with a quencehr and labeled at the 3' end with a fluorophore; (b) contacting the cell with a compound or a member of a library of compounds; and (c) measuring the activity of the tRNA splicing endonuclease, wherein an antiproliferative compound that inhibits or reduces tRNA splicing activity is identified if a fluorescent signal is not detectable in the presence of the compound relative to the absence of the compound or the presence of a control. In another embodiment, the invention provides a method of identifying an antiproliferative compound that inhibits or reduces human tRNA splicing endonuclease activity, said method comprising: (a) contacting a human cell containing a substrate of a tRNA splicing endonuclease with a compound or a member of a library of compounds, wherein the substrate is labeled at the 5' end with a fluorophore and at the 3' end with a quencher, or alternatively, the substrate is labeled at the 5' end with a quencehr and labeled at the 3' end with a fluorophore; and (b) measuring the activity of the tRNA splicing endonuclease, wherein an antiproliferative compound that inhibits or reduces tRNA splicing activity is identified if a fluorescent signal is not detectable in the presence of the compound relative to the absence of the compound or the presence of a control.

15 In another embodiment, the invention provides a method of identifying an antiproliferative compound that inhibits or reduces human tRNA splicing endonuclease activity, said method comprising: (a) microinjecting or transfecting a substrate of a tRNA splicing endonuclease into a human cell, wherein the substrate is labeled at the 5' end with a fluorescent donor moiety and labeled at the 3' end with a fluorescent acceptor moiety, or alternatively, the substrate is labeled at the 5' end with a fluorescent acceptor moiety and labeled at the 3' end with a fluorescent donor moiety; (b) contacting the cell with a compound or a member of a library of compounds; and (c) measuring the activity of the tRNA splicing endonuclease, wherein an antiproliferative compound that inhibits or reduces tRNA splicing activity is identified if the fluorescent signal detected in the presence of the compound is altered relative to the absence of the compound or the presence of a control. In another embodiment, the invention provides a method of identifying an antiproliferative compound that inhibits or reduces human tRNA splicing endonuclease activity, said method comprising: (a) contacting a human cell containing substrate of a tRNA splicing endonuclease with a compound or a member of a library of compounds, wherein the substrate is labeled at the 5' end with a fluorescent donor moiety and labeled at the 3' end with a fluorescent acceptor moiety, or alternatively, the substrate is labeled at the 5' end with a fluorescent acceptor moiety and labeled at the 3' end with a fluorescent donor moiety; and (b) measuring the activity of the tRNA splicing endonuclease, wherein an antiproliferative compound that inhibits or reduces tRNA splicing activity is identified if the

fluorescence emission of the fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety in the presence of the compound is reduced relative to the absence of the compound or the presence of a control.

5 The activity of a compound on a human tRNA splicing endonuclease or a 3' end pre-mRNA endonuclease in the FRET cell-based assays can be determined by measuring the fluorescent emission spectra of the substrate utilizing techniques well-known to one of skill in the art. The fluorescent emission spectra measured depends, in part, on the fluorophore used.

#### 4.5.6.2 Cell-Free Assays with a Labeled Substrate

10 The FRET cell-free assays for human tRNA splicing endonuclease may be conducted by contacting a substrate for a human tRNA splicing endonuclease with a cell-free extract (see Section 4.4.1.2 *supra* regarding cell-free extracts, preferably, a tRNA splicing endonuclease extract) or a purified human tRNA splicing endonuclease and a compound, wherein the substrate is labeled at the 5' end with a fluorophore and labeled at the 3' end with a quencher or,  
15 alternatively, the the substrate is labeled at the 3' end with a fluorophore and labeled at the 5' end with a quencher, and measuring the fluorescence of the substrate in, *e.g.*, a fluorescence emission detector such as a Viewlux or Analyst. The tRNA splicing endonuclease in the cell-free extract will cleave the substrate and result in the production of a detectable fluorescent signal. A compound that inhibits or reduces the activity of the tRNA splicing endonuclease will  
20 inhibit or reduce the cleavage of the substrate and thus, inhibit or reduce the production of a detectable fluorescent signal relative to a negative control (*e.g.*, PBS). A compound that enhances the activity of the tRNA splicing endonuclease will enhance the cleavage of the substrate and thus, increase the production of a detectable signal relative to a negative control (*e.g.*, PBS).

25 Alternatively, the FRET cell-free-based assays for human tRNA splicing endonuclease may be conducted by contacting a substrate for a human tRNA splicing endonuclease with a cell-free extract (preferably, a tRNA splicing endonuclease extract) or a purified human tRNA splicing endonuclease and a compound, wherein the substrate is labeled at the 5' end with a fluorescent donor moiety and labeled at the 3' end with a fluorescent acceptor moiety, or  
30 alternatively, the substrate is labeled at the 5' end with a fluorescent acceptor moiety and labeled at the 3' end with a fluorescent donor moiety, and measuring the fluorescence of the substrate by, *e.g.*, a fluorescence emission detector such as a Viewlux or Analyst. The tRNA splicing

endonuclease will cleave the substrate and result in the production of a detectable fluorescent signal by the fluorescent donor moiety and fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety. A compound that inhibits or reduces the activity of the tRNA splicing endonuclease will inhibit or reduce cleavage of the substrate and thus, increase the fluorescence emission of the fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety relative to a negative control (*e.g.*, PBS). A compound that enhances the activity of the tRNA splicing endonuclease will enhance the cleavage of the substrate and thus, reduce the fluorescence emission of the fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety relative to a negative control (*e.g.*, PBS). In a preferred embodiment, a negative control (*e.g.*, PBS or another agent that is known to have no effect on the cleavage of the substrate) and a positive control (*e.g.*, an agent that is known to have an effect on the cleavage of the substrate) are included in the FRET cell-free assays described herein.

The FRET cell-free assays for human 3' end mRNA endonuclease may be conducted by contacting a substrate for a human 3' end pre-mRNA endonuclease with a cell-free extract (see Section 4.4.1.2 *supra* regarding cell-free extracts, preferably, a tRNA splicing endonuclease extract) or a purified human 3' end pre-mRNA endonuclease and a compound, wherein the substrate is labeled at the 5' end with a fluorophore and labeled at the 3' end with a quencher or, alternatively, the substrate is labeled at the 3' end with a fluorophore and labeled at the 5' end with a quencher, and measuring the fluorescence of the substrate in, *e.g.*, a fluorescence emission detector such as a Viewlux or Analyst. The 3' end pre-mRNA endonuclease in the cell-free extract will cleave the substrate and result in the production of a detectable fluorescent signal. A compound that inhibits or reduces the activity of the 3' end pre-mRNA endonuclease will inhibit or reduce the cleavage of the substrate and thus, inhibit or reduce the production of a detectable fluorescent signal relative to a negative control (*e.g.*, PBS). A compound that enhances the activity of the 3' end pre-mRNA endonuclease will enhance the cleavage of the substrate and thus, increase the production of a detectable signal relative to a negative control (*e.g.*, PBS).

The FRET cell-free assays for human 3' end mRNA endonuclease may be conducted by contacting a substrate for a human 3' end pre-mRNA endonuclease with a cell-free extract (see Section 4.4.1.2 *supra* regarding cell-free extracts, preferably, a tRNA splicing endonuclease extract) or a purified human 3' end pre-mRNA endonuclease and a compound, wherein the substrate is labeled at the 5' end with a fluorophore donor and labeled at the 3' end with a fluorophore acceptor or, alternatively, the substrate is labeled at the 3' end with a fluorophore



donor and labeled at the 5' end with a fluorophore acceptor, and measuring the fluorescence of the substrate in, *e.g.*, a fluorescence emission detector such as a Viewlux or Analyst. The 3' end pre-mRNA endonuclease or tRNA splicing endonuclease in the cell-free extract will cleave the substrate and result in the production of a detectable fluorescent signal. A compound that

5 inhibits or reduces the activity of the 3' end pre-mRNA endonuclease or tRNA splicing endonuclease will inhibit or reduce the cleavage of the substrate and thus, increase the production of a detectable signal relative to a negative control (*e.g.*, PBS). A compound that enhances the activity of the 3' end pre-mRNA endonuclease or tRNA splicing endonuclease will enhance the cleavage of the substrate and thus, inhibit or reduce the production of a detectable

10 fluorescent signal relative to a negative control (*e.g.*, PBS).

A FRET assay can be conducted in any buffer system that provides conditions conducive to the tRNA endonuclease reaction. Such buffer systems are well known to the skilled artisan. In a specific embodiment, the buffer comprises 20 mM Tris at a pH of 7.0, 50 mM KCl, 0.1 mM DTT, 5 mM MgCl<sub>2</sub>, and 0.4% Triton X100. Care should be taken that pH, salt

15 concentration, detergent concentration etc. of the buffer system do not interfere with FRET.

In certain embodiments, the assay is conducted for at least 0.2 hours, 0.25 hours, 0.5 hours, 1 hour, 2 hours, 3 hours, 4 hours, 5 hours, 6 hours, 8 hours, 10 hours, 12 hours, 18 hours, or at least 1 day.

In one embodiment, the invention provides a method of identifying an antiproliferative

20 compound that inhibits or reduces human tRNA splicing endonuclease activity, said method comprising: (a) contacting a human cell-free extract (preferably, a tRNA splicing endonuclease extract) or a purified human tRNA splicing endonuclease with a substrate of a tRNA splicing endonuclease and a member of a library of compounds, wherein the substrate is labeled at the 5' end with a fluorophore and labeled at the 3' end with a quencher, or alternatively, the substrate

25 is labeled at the 5' end with a quencher and labeled at the 3' end with a fluorophore; and (b) measuring the activity of the tRNA splicing endonuclease, wherein an antiproliferative compound that inhibits or reduces tRNA splicing activity is identified if a fluorescent signal is not detectable in the presence of the compound relative to the absence of the compound or the presence of a control. In another embodiment, the invention provides a method of identifying an

30 antiproliferative compound that inhibits or reduces human tRNA splicing endonuclease activity, said method comprising: (a) contacting a human cell-free extract (preferably, a tRNA splicing endonuclease extract) or a purified human tRNA splicing endonuclease with a substrate of a tRNA splicing endonuclease and a member of a library of compounds, wherein said substrate is

labeled at the 5' end with a fluorescent donor moiety and labeled at the 3' end with a fluorescent acceptor moiety, or alternatively, the substrate is labeled at the 5' end with a fluorescent acceptor moiety and labeled at the 3' end with a fluorescent donor moiety; and (b) measuring the activity of the tRNA splicing endonuclease, wherein an antiproliferative compound that inhibits tRNA splicing activity is identified if the fluorescence emission of the fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety detected in the presence of the compound is decreased relative to the absence of the compound or the presence of a control.

In one embodiment, the invention provides a method of identifying an antiproliferative compound that inhibits or reduces human 3' pre-mRNA endonuclease activity, said method comprising: (a) contacting a human cell-free extract (preferably, a 3' pre-mRNA endonuclease extract) or a purified human 3' pre-mRNA endonuclease with a substrate of a 3' pre-mRNA endonuclease and a member of a library of compounds, wherein the substrate is labeled at the 5' end with a fluorophore and labeled at the 3' end with a quencher, or alternatively, the substrate is labeled at the 5' end with a quencher and labeled at the 3' end with a fluorophore; and (b) measuring the activity of the 3' pre-mRNA endonuclease, wherein an antiproliferative compound that inhibits or reduces 3' pre-mRNA endonuclease activity is identified if a fluorescent signal is not detectable in the presence of the compound relative to the absence of the compound or the presence of a control. In another embodiment, the invention provides a method of identifying an antiproliferative compound that inhibits or reduces human 3' pre-mRNA endonuclease activity, said method comprising: (a) contacting a human cell-free extract (preferably, a 3' pre-mRNA endonuclease extract) or a purified human 3' pre-mRNA endonuclease with a substrate of a tRNA splicing endonuclease and a member of a library of compounds, wherein said substrate is labeled at the 5' end with a fluorescent donor moiety and labeled at the 3' end with a fluorescent acceptor moiety, or alternatively, the substrate is labeled at the 5' end with a fluorescent acceptor moiety and labeled at the 3' end with a fluorescent donor moiety; and (b) measuring the activity of the 3' pre-mRNA endonuclease, wherein an antiproliferative compound that inhibits tRNA splicing activity is identified if the fluorescence emission of the fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety detected in the presence of the compound is decreased relative to the absence of the compound or the presence of a control.

The activity of a compound on a human tRNA splicing endonuclease or 3' pre-mRNA endonuclease in the FRET cell-free assays can be determined by measuring the fluorescent emission spectra of the substrate utilizing techniques well-known to one of skill in the art. The

fluorescent emission spectra measured depends, in part, on the fluorophore used.

#### 4.5.6.3 Cell-Based Assays with Labeled Enzyme

A FRET cell-based assay may be conducted by microinjecting or transfecting a first  
5 subunit of a human tRNA splicing endonuclease (see Table 1 for the components of the complex) labeled with a fluorophore and a second, different subunit of a human tRNA splicing endonuclease (see Table 1 for the components of the complex) labeled with a quencher into a cell and contacting the cell with a compound, and measuring the fluorescence of the human tRNA splicing endonuclease by, *e.g.*, fluorescence microscopy or a fluorescence emission  
10 detector such as a Viewlux or Analyst. Preferably, the cell microinjected or transfected is deficient in one or more of the subunits of the human tRNA splicing endonuclease. Any methods known to the skilled artisan can be used to remove the expression and/or function of one or more subunits of the human tRNA splicing endonuclease from the cell. In a specific embodiment, RNAi is used to transiently remove one or more of the subunits of the human  
15 tRNA splicing endonuclease. The formation of the human tRNA splicing endonuclease from the labeled subunits will result in a reduction in the fluorescence detectable. A compound that inhibits or reduces the formation of the human tRNA splicing endonuclease will reduce or inhibit the production of a detectable fluorescent signal relative to a negative control (*e.g.*, PBS). A compound that enhances the formation of the human tRNA splicing endonuclease will  
20 increase the fluorescence detectable relative to a negative control (*e.g.*, PBS).

Alternatively, a FRET cell-based assay may be conducted by microinjecting a first subunit of a human tRNA splicing endonuclease (*e.g.*, SEN2) labeled with a fluorescent donor moiety and a second, different subunit of a human tRNA splicing endonuclease (*e.g.*, SEN34) labeled with a fluorescent acceptor moiety into a cell and contacting the cell with a compound,  
25 and measuring the fluorescence of the human tRNA splicing endonuclease by, *e.g.*, fluorescence microscopy or a fluorescence emission detector such as a Viewlux or Analyst. The formation of the human tRNA splicing endonuclease will result in the production of a detectable fluorescent signal by the fluorescent donor moiety and fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety. A compound that inhibits or reduces the formation of the human  
30 tRNA splicing endonuclease will reduce the fluorescence emission of the fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety relative to a negative control (*e.g.*, PBS). A compound that enhances the formation of the human tRNA splicing endonuclease will

increase the fluorescence emission of the fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety relative to a negative control (*e.g.*, PBS). In a preferred embodiment, a negative control (*e.g.*, PBS or another agent that is known to have no effect on the cleavage of the substrate) and a positive control (*e.g.*, an agent that is known to have an effect on the  
5 cleavage of the substrate) are included in the FRET cell-based assays described herein.

In certain embodiments, the compound and the cell are incubated for at least 0.2 hours, 0.25 hours, 0.5 hours, 1 hour, 2 hours, 3 hours, 4 hours, 5 hours, 6 hours, 8 hours, 10 hours, 12 hours, 18 hours, or at least 1 day.

Methods for labeling a subunit of a human tRNA splicing endonuclease with a  
10 fluorescent acceptor moiety, a fluorescent donor moiety and/or quencher are well-known in the art (see, *e.g.*, U.S. Patent Nos. 6,472,156, 6,451,543, 6,348,322, 6,342,379, 6,323,039, 6,297,018, 6,291,201, 6,280,981, 5,843,658, and 5,439,797, the disclosures of which are incorporated by reference in their entirety).

Such an assay can analogously be used to identify modulators of 3' end pre-mRNA  
15 processing, rRNA endonuclease or tRNA endonuclease activity.

#### **4.5.6.4 Cell-Free Assays with Labeled Enzyme**

A FRET cell-free assay may be conducted by contacting a first subunit of a human tRNA splicing endonuclease (see Table 1 for the components of the complex) labeled with a  
20 fluorophore and a second subunit of a human tRNA splicing endonuclease (see Table 1 for the components of the complex) labeled with a quencher with a compound *in vitro* under conditions conducive to the formation of the endonuclease, and measuring the fluorescence of the human tRNA splicing endonuclease by, *e.g.*, a fluorescence emission detector such as a Viewlux or Analyst. The formation of the human tRNA splicing endonuclease from the labeled subunits  
25 will result in a reduction in the fluorescence detectable. A compound that inhibits or reduces the formation of the human tRNA splicing endonuclease will enhance the production of detectable fluorescent signal relative to the absence of the compound or the presence of a negative control (*e.g.*, PBS). A compound that enhances the formation of the human tRNA splicing endonuclease will reduce or inhibit the fluorescence detectable relative to the absence of the  
30 compound or a negative control (*e.g.*, PBS).

Alternatively, a FRET cell-free assay may be conducted by contacting a first subunit of a human tRNA splicing endonuclease (*e.g.*, SEN2) labeled with a fluorescent donor moiety and a

second, different subunit of a human tRNA splicing endonuclease (*e.g.*, SEN34) labeled with a fluorescent acceptor moiety with a compound *in vitro* under conditions conducive to the formation of the endonuclease, and measuring the fluorescence of the human tRNA splicing endonuclease by, *e.g.*, a fluorescence emission detector such as a Viewlux or Analyst. The formation of the human tRNA splicing endonuclease will result in the production of a detectable fluorescent signal by the fluorescent donor moiety and fluorescent acceptor moiety at the wavelength of the fluorescent donor. A compound that inhibits or reduces the formation of the human tRNA splicing endonuclease will reduce the fluorescence emission of the fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety relative to the absence of the compound or the presence of a negative control (*e.g.*, PBS). A compound that enhances the formation of the human tRNA splicing endonuclease will increase the fluorescence emission of the fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety relative to the absence of the compound or the presence of a negative control (*e.g.*, PBS). In a preferred embodiment, a negative control (*e.g.*, PBS or another agent that is known to have no effect on the cleavage of the substrate) and a positive control (*e.g.*, an agent that is known to have an effect on the cleavage of the substrate) are included in the FRET cell-free assays described herein.

Such an assay can analogously be used to identify modulators of 3' end pre-mRNA processing, rRNA endonuclease or tRNA endonuclease activity.

#### **4.5.7 Direct Binding Assays**

Compounds that modulate the activity of pre-tRNA splicing endonuclease, 3' end pre-mRNA endonuclease, pre-tRNA cleavage or pre-rRNA cleavage can be identified by direct binding assays. In particular, compounds that inhibit the activity of a human pre-tRNA splicing endonuclease, 3' end pre-mRNA endonuclease, pre-tRNA cleavage or pre-rRNA cleavage by directly or indirectly reducing or inhibiting the interaction between a substrate and a complex of the invention. The pre-tRNA splicing endonuclease, a 3' end pre-mRNA endonuclease, a pre-tRNA cleavage complex or a pre-rRNA cleavage complex can be purified. Such assays are described in International Patent Publication Nos. WO 02/083837 and WO 02/083953, the disclosures of which are hereby incorporated by reference in their entireties. Briefly, direct binding assays may be conducted by attaching a library of compounds to solid supports, *e.g.*,

polymer beads, with each solid support having substantially one type of compound attached to its surface. The plurality of solid supports of the library is exposed in aqueous solution to a substrate for a pre-tRNA splicing endonuclease, a 3' end pre-mRNA endonuclease, a pre-tRNA cleavage complex or a pre-rRNA cleavage complex having a detectable label, forming a dye-labeled substrate:support-attached compound complex. Binding of a substrate to a particular compound labels the solid support, *e.g.*, bead, comprising the compound, which can be physically separated from other, unlabeled solid supports. Once labeled solid supports are identified, the chemical structures of the compounds thereon can be determined by, *e.g.*, reading a code on the solid support that correlates with the structure of the attached compound.

Alternatively, direct binding assays may be conducted by contacting a substrate for a pre-tRNA splicing endonuclease, a 3' end pre-mRNA endonuclease, a pre-tRNA cleavage complex or a pre-rRNA cleavage complex having a detectable label with a compound or a member of a library of compounds free in solution, in labeled tubes or microtiter wells, or a microarray. Compounds in the library that bind to the labeled substrate of a pre-tRNA splicing endonuclease, a 3' end pre-mRNA endonuclease, a pre-tRNA cleavage complex or a pre-rRNA cleavage complex will form a detectably labeled complex that can be identified and removed from the uncomplexed, unlabeled compounds in the library, and from uncomplexed, labeled substrate of a pre-tRNA splicing endonuclease, a 3' end pre-mRNA endonuclease, a pre-tRNA cleavage complex or a pre-rRNA cleavage complex, by a variety of methods including, but not limited to, methods that differentiate changes in the electrophoretic, chromatographic, or thermostable properties of the complexed substrate.

#### **4.5.8 Fluorescence Polarization Assay**

The effect of a compound on the activity of a pre-tRNA splicing endonuclease, a 3' end pre-mRNA endonuclease, a pre-tRNA cleavage complex or a pre-rRNA cleavage complex may be determined utilizing a fluorescence polarization-based assay. In such an assay, a fluorescently labeled substrate for pre-tRNA splicing endonuclease, a 3' end pre-mRNA endonuclease, a pre-tRNA cleavage complex or a pre-rRNA cleavage complex is contacted with a cell-free extract (preferably, human tRNA splicing endonuclease extract or a human 3' end pre-mRNA processing extract) or a purified pre-tRNA splicing endonuclease, a purified 3' end pre-mRNA endonuclease, a purified pre-tRNA cleavage complex or a purified pre-rRNA cleavage complex and a compound or a member of a library of compounds; and the fluorescently

polarized light emitted is measured. An important aspect of this assay is that the size of the substrate used in the assay is large enough to distinguish a change in fluorescent polarized light emitted following cleavage of the substrate.

In certain embodiments, substrates for the FP assay can be labeled with a fluorophore by  
5 any method known to the skilled artisan.

The pre-tRNA splicing endonuclease, a 3' end pre-mRNA endonuclease, a pre-tRNA cleavage complex or a pre-rRNA cleavage complex will cleave the substrate and result in a change in intensity of emitted polarized light. Fluorescently labeled substrates when excited with plane polarized light will emit light in a fixed plane only if they do not rotate during the  
10 period between excitation and emission. The extent of depolarization of the emitted light depends upon the amount of rotation of the substrate, which is dependent on the size of the substrate. Small substrates rotate more than larger substrates between the time they are excited and the time they emit fluorescent light. A small fluorescently labeled substrate rotates rapidly and the emitted light is depolarized. A large fluorescently labeled substrate rotates more slowly  
15 and results in the emitted light remaining polarized. A compound that inhibits the activity of the pre-tRNA splicing endonuclease, a 3' end pre-mRNA endonuclease, a pre-tRNA cleavage complex or a pre-rRNA cleavage complex will inhibit or reduce the cleavage of the substrate and thus, decrease the rotation of the substrate relative to a negative control (*e.g.*, PBS) or the absence of the compound, which will result in the emitted light remaining polarized. A  
20 compound that enhances the activity of the pre-tRNA splicing endonuclease, a 3' end pre-mRNA endonuclease, a pre-tRNA cleavage complex or a pre-rRNA cleavage complex will enhance the cleavage of the substrate and thus, increase the rotation of the substrate relative to a negative control (*e.g.*, PBS) or the absence of the compound, which will result in more of the emitted light being depolarized.

25 The intensities of the light are measured in planes 90° apart and are many times designated the horizontal and vertical intensities. In some instruments the excitation filter is moveable while the emission filter is fixed. In certain other machines the horizontal and vertical intensities are measured simultaneously via fiber optics. Research grade fluorescence polarization instruments are commercially available from, *e.g.*, Pan Vera, BMG Lab  
30 Technologies, and LJI Biosystems. Abbott provides clinical laboratory instrumentation. The value of fluorescence polarization is determined by the following equation:

$$\text{polarization} = \frac{\text{intensity}_{\text{vertical}} - \text{intensity}_{\text{horizontal}}}{\text{intensity}_{\text{vertical}} + \text{intensity}_{\text{horizontal}}}$$

Fluorescence polarization values are most often divided by 1000 and expressed as millipolarization units (mP).

5 In a specific embodiment, the hybridized tRNA or circularly permuted tRNA depicted in Figure 1 are used as a substrate for the pre-tRNA splicing endonuclease complex. In accordance with this embodiment, the 5' end in the intron of the hybridized tRNA or the circularly permuted tRNA, or the 3' end in the intron of the hybridized tRNA or the circularly permuted tRNA or both are labeled with a fluorophore. Upon cleavage, the size of the molecule to which the  
10 fluorophore is attached changes because the intron is released from the substrate. The decrease in molecular weight of the labeled molecule results in an increase of depolarization of light that is emitted from the fluorophore. Measuring the amount of depolarization allows the skilled artisan to determine the amount of cleaved substrate.

#### 15 **4.5.9 tRNA Endonuclease Suppression Assay**

The effect of a compound or a member of a library of compounds on the activity of a human tRNA splicing endonuclease may be determined using a tRNA endonuclease suppression assay. In such an assay, a host cell is engineered to contain a first reporter gene construct and a suppressor tRNA; the expression of the suppressor tRNA is induced; the host cell is contacted  
20 with a compound or a member of a library of compounds; and the expression of the reporter gene and/or the activity of the protein encoded by the reporter gene is measured. The first reporter gene construct comprises a reporter gene with a nonsense codon in its open reading frame such that the open reading frame is interrupted. Standard mutagenesis techniques described, *e.g.*, in Sambrook (Sambrook, 1989, Molecular Cloning, A Laboratory Manual,  
25 Second Edition; DNA Cloning, Volumes I and II (Glover, Ed. 1985)) may be used to introduce a nonsense codon into the open reading frame of any reporter gene well-known to one of skill in the art. The first reporter gene construct is transfected into a host cell engineered to contain a suppressor tRNA. Alternatively, the first reporter gene is cotransfected into a host cell with a suppressor tRNA. The suppressor tRNA's expression is regulated by a controllable regulatory  
30 element; such as by a tetracycline regulated regulatory element (see, *e.g.*, Buvoli et al, 2000, Molecular and Cellular Biology 20:3116-3124; Park and Bhandary, 1998, Molecular and Cellular Biology 18:4418-4425) and the suppressor tRNA contains a tRNA intron in the



anticodon stem such that only properly spliced suppressor tRNA is functional. Expression of functional suppressor tRNA is dependent on (i) the transcription of the suppressor tRNA, and (ii) tRNA splicing. The expression of functional suppressor tRNA suppresses the nonsense codon in the reporter gene and results in full length, functional reporter gene expression.

5 Accordingly, the expression of full length, functional reporter gene correlates with the expression of functional suppressor tRNA, which in turn correlates with the level of transcription of the suppressor tRNA and tRNA splicing. The expression of full-length reporter gene and the activity of the protein encoded by the reporter gene can be assayed by any method well known to the skilled artisan or as described herein.

10 A compound that inhibits or reduces the activity of a human tRNA splicing endonuclease will inhibit or reduce the production of functional suppressor tRNA and thus, reduce the expression of the reporter gene relative to a previously determined reference range or a control. A compound that enhances the activity of a human tRNA splicing endonuclease will enhance the production of functional suppressor tRNA and thus, enhance the production of the reporter  
15 gene relative to a previously determined reference range or a control.

The step of inducing the expression of the suppressor tRNA may be conducted simultaneously with the step of contacting the host cell with a compound or at least 5 minutes, at least 15 minutes, at least 0.5 hours, at least 1 hour, at least 1.5 hours, at least 2 hours, at least 3 hours, at least 4 hours, at least 5 hours, at least 6 hours, at least 8 hours, at least 10 hours or at  
20 least 12 hours before the step of contacting the compound with the host cell. In certain embodiments, the expression of the suppressor tRNA is induced by incubating the host cell with an agent such as, *e.g.*, tetracycline, for approximately 5 minutes, approximately 15 minutes, approximately 0.5 hours, approximately 1 hour, approximately 1.5 hours, approximately 2 hours, approximately 3 hours, approximately 4 hours, approximately 5 hours, 6 approximately  
25 hours, 8 approximately hours, approximately 10 hours or approximately 12 hours. In other embodiments, the host cell is contacted with the compound for approximately 5 minutes, approximately 15 minutes, approximately 0.5 hours, approximately 1 hour, approximately 1.5 hours, approximately 2 hours, approximately 3 hours, approximately 4 hours, approximately 5 hours, 6 approximately hours, 8 approximately hours, approximately 10 hours or approximately  
30 12 hours.

Optionally, the host cell is engineered to contain a second reporter gene construct comprising a reporter gene different from the first reporter gene that does not contain a nonsense codon. In a specific embodiment, the reporter genes used in the tRNA endonuclease

suppression assay are Red and Green Click Beetle luciferase, wherein the Red luciferase contains the nonsense codon. A host cell may be engineered to stably express the two luciferase genes and the suppressor tRNA whose expression is regulated by a controlled regulatory element (such as a tetracycline controlled regulatory element). In the absence of an agent such as tetracycline, the suppressor tRNA is not expressed and thus the red-to-green ratio is low. In the presence of an agent such as tetracycline, the suppressor tRNA is expressed and thus the red-to-green ratio increases. For a high throughput screening, cells are plated in the presence of a compound. After a certain time-period media containing an agent such as tetracycline is added to induce suppressor tRNA expression.

Compounds that inhibit tRNA splicing endonuclease will decrease the red-to-green ration compared to a control without the compound. Once compounds are identified in this assay that modulate the activity of human tRNA splicing endonuclease, they may be tested using one or more of the assays described above to confirm their activity.

#### **4.5.10 FISH Assay**

The activity of a tRNA splicing endonuclease may be determined in an assay in which the persistence and quantity of tRNA intron is detected in a human cell. The amount of tRNA intron is quantified at different time points after or during the incubation of the cell with the compound. The tRNA intron can be detected by means of Fluorescence *in situ* hybridization (FISH) using a tRNA intron-specific probe. In certain embodiments, a control experiment is conducted in parallel wherein the human cell is not contacted with a compound.

In the absence of an inhibitor of human tRNA splicing endonuclease, the splicing reaction is fast and the concentration of intron in the cell is low. Without being bound by theory, because the spliced intron is normally degraded the concentration of tRNA intron in the human cell is below the detection threshold. In the presence of an inhibitor of human tRNA splicing endonuclease, the splicing reaction is slowed down and the amount of tRNA intron increases. Thus, a compound that inhibits human tRNA splicing endonuclease can be identified by its ability to increase the level of tRNA intron in the human cell.

Similarly, the activity of 3' end pre-mRNA endonuclease complex can be determined using FISH via measuring the amount of polyadenylated mRNA. An increased level of polyadenylated mRNA indicates increased activity of 3' end pre-mRNA endonuclease complex. Thus, if the assay is performed in the presence of a compound and the level of polyadenylated

mRNA is increased the compound is an activator of 3' end pre-mRNA endonuclease complex. If the level of polyadenylated mRNA is decreased in the presence of a compound, the compound is an antagonist of 3' end pre-mRNA endonuclease complex. Alternatively, the part of the pre-mRNA that is 3' of the cleavage site can be detected; increased level of the part of the pre-mRNA that is 3' of the cleavage site indicates a decreased activity of 3' end pre-mRNA endonuclease complex. Thus, if the assay is performed in the presence of a compound and the level of polyadenylated mRNA is increased the compound is an antagonist of 3' end pre-mRNA endonuclease complex. If the level of polyadenylated mRNA is decreased in the presence of a compound, the compound is an activator of 3' end pre-mRNA endonuclease complex.

Methods for conducting FISH are well-known to the skilled artisan and can be used with the invention. Exemplary methods for FISH are described in Sarkar and Hopper, 1998 (Mol. Biol. Cell 9:3041-3055), which is incorporated herein in its entirety.

In certain embodiments, a FISH assay is used to determine the effect of a compound on the activity of a human tRNA splicing endonuclease or 3' end pre-mRNA endonuclease in a high-throughput screen. In particular a 96-lens microscope can be used for a high-throughput screen based on FISH. In a specific embodiment, 96 cell cultures are incubated in a 96-well plate with different compounds. Subsequently, the cells are subjected to a FISH analysis using a tRNA intron specific probe or a 3' end pre-mRNA specific probe and analyzed using the 96-lens microscope. The presence of a signal or the presence of a significantly stronger signal demonstrates that tRNA intron or 3' end pre-mRNA, respectively, was present in the cells at elevated levels and thus the compound is a candidate inhibitor of tRNA splicing endonuclease or pre-mRNA endonuclease activity, respectively.

Without being bound by theory, the FISH assay identifies the compound as inhibitor of the tRNA splicing endonuclease or 3' end pre-mRNA endonuclease directly. Thus, in certain embodiments, a compound that was identified in a FISH assay as an inhibitor of tRNA splicing or 3' end pre-mRNA endonuclease activity, respectively, is a *prima facie* candidate for an inhibitor of tRNA splicing endonuclease.

#### **4.5.11 Other Screening Assays**

The activity of a human tRNA splicing endonuclease, 3' end pre-mRNA endonuclease, pre-tRNA cleavage endonuclease or ribosomal RNA endonuclease may be determined in an assay in which the amount of substrate for a tRNA splicing endonuclease, 3' end pre-mRNA

endonuclease, pre-tRNA cleavage endonuclease or ribosomal RNA endonuclease, respectively, cleaved by the endonuclease in the presence of a compound relative to a control (preferably, a negative control and more preferably, a negative control and a positive control) is detected. Such an assay may be conducted by contacting or incubating a compound with a labeled  
5 substrate for an tRNA splicing endonuclease, 3' end pre-mRNA endonuclease, pre-tRNA cleavage endonuclease or ribosomal RNA endonuclease, respectively and a cell-free extract or purified tRNA splicing endonuclease, 3' end pre-mRNA endonuclease, pre-tRNA cleavage endonuclease or ribosomal RNA endonuclease under conditions conducive for endonuclease activity, and measuring the amount of cleaved substrate. The substrate can be labeled with any  
10 detectable agent. Useful labels in the present invention can include, but are not limited to, spectroscopic labels such as fluorescent dyes (*e.g.*, fluorescein and derivatives such as fluorescein isothiocyanate (FITC) and Oregon Green™, rhodamine and derivatives (*e.g.*, Texas red, tetramethylrhodimine isothiocyanate (TRITC), bora-3a,4a-diaza-s-indacene (BODIPY®) and derivatives, *etc.*), digoxigenin, biotin, phycoerythrin, AMCA, CyDye™, and the like),  
15 radiolabels (*e.g.*, <sup>3</sup>H, <sup>125</sup>I, <sup>35</sup>S, <sup>14</sup>C, <sup>32</sup>P, <sup>33</sup>P, *etc.*), enzymes (*e.g.*, horse radish peroxidase, alkaline phosphatase *etc.*), spectroscopic colorimetric labels such as colloidal gold or colored glass or plastic (*e.g.*, polystyrene, polypropylene, latex, *etc.*) beads, or nanoparticles – nanoclusters of inorganic ions with defined dimension from 0.1 to 1000 nm) utilizing techniques known to one of skill in the art.

20 For example, a substrate can be labeled by any method known to the skilled artisan. In certain embodiments, a substrate can be labeled using site-specific labeling of RNA with fluorophores. In more specific embodiments, a substrate is labeled using the methods described in Qin and Pyle, 1999 (Methods 18(1):60-70), which is incorporated in its entirety herein. The optimal method for labeling of a substrate can be determined by the skilled artisan using routine  
25 experimentation. In a specific embodiment, a substrate is labeled using different methods, different labels and/or different positions in the substrate. The differently labeled substrates are then subjected separately to a splicing assay in the presence and absence, respectively of an inhibitor or an activator of an endonuclease. The optimal label for the screening assays is the label that allows for the most easily detectable and most reproducible detection of the effect of  
30 the inhibitor or the activator. Other labeling procedures, however, may also be used that, for example, provide other desirable advantages.

In certain embodiments, a compound is contacted or incubated with a labeled substrate and a cell-free extract or purified endonuclease complex of the invention for at least 5 minutes,

at least 10 minutes, at least 15 minutes, at least 30 minutes, at least 1 hour, at least 2 hours, or more. The amount of cleaved substrate is proportional to the activity of the endonuclease. The amount of cleavage product can be measured by any technique known to one skilled in the art.

In certain embodiments, the cleaved product is separated from the uncleaved RNA  
5 substrate by gel-electrophoresis. The amount of cleaved product can be quantified by measuring the intensity of the signal of the cleaved substrate. The stronger the signal produced by the cleaved product relative to the uncleaved substrate the more active is the endonuclease. The signal intensity can be quantified using autoradiography or a phosphoimager. If the activity of the endonuclease is decreased in the presence of a compound, *i.e.*, if the signal of the cleaved  
10 product relative to the uncleaved substrate is decreased compared to the reaction without the compound or in the presence of a negative control, the compound is identified as an inhibitor of the endonuclease.

In other embodiments, the amount of cleaved product is determined using mass  
spectrometry.

15

#### **4.5.12 Compounds**

Any molecule known in the art can be tested for its ability to modulate (increase or decrease) the amount of, activity of, or protein component composition of a complex of the present invention as detected by a change in the amount of, activity of, or protein component  
20 composition of, said complex. By way of example, a change in the amount of the complex can be detected by detecting a change in the amount of the complex that can be isolated from a cell expressing the complex machinery. In other embodiments, a change in signal intensity (*e.g.*, when using FRET or FP) in the presence of a compound compare to the absence of the compound indicates that the compound is a modulator of complex formation. For identifying a  
25 molecule that modulates complex activity, candidate molecules can be directly provided to a cell expressing the complex, or, in the case of candidate proteins, can be provided by providing their encoding nucleic acids under conditions in which the nucleic acids are recombinantly expressed to produce the candidate proteins within the cell expressing the complex machinery, the complex is then purified from the cell and the purified complex is assayed for activity using  
30 methods well known in the art, not limited to those described, *supra*.

In certain embodiments, the invention provides screening assays using chemical libraries for molecules which modulate, *e.g.*, inhibit, antagonize, or agonize, the amount of, activity of, or

protein component composition of the complex. The chemical libraries can be peptide libraries, peptidomimetic libraries, chemically synthesized libraries, recombinant, *e.g.*, phage display libraries, and *in vitro* translation-based libraries, other non-peptide synthetic organic libraries, etc.

5 Exemplary libraries are commercially available from several sources (ArQule, Tripos/PanLabs, ChemDesign, Pharmacopoeia). In some cases, these chemical libraries are generated using combinatorial strategies that encode the identity of each member of the library on a substrate to which the member compound is attached, thus allowing direct and immediate identification of a molecule that is an effective modulator. Thus, in many combinatorial  
10 approaches, the position on a plate of a compound specifies that compound's composition. Also, in one example, a single plate position may have from 1-20 chemicals that can be screened by administration to a well containing the interactions of interest. Thus, if modulation is detected, smaller and smaller pools of interacting pairs can be assayed for the modulation activity. By such methods, many candidate molecules can be screened.

15 Many diversity libraries suitable for use are known in the art and can be used to provide compounds to be tested according to the present invention. Alternatively, libraries can be constructed using standard methods. Chemical (synthetic) libraries, recombinant expression libraries, or polysome-based libraries are exemplary types of libraries that can be used.

The libraries can be constrained or semirigid (having some degree of structural rigidity),  
20 or linear or non-constrained. The library can be a cDNA or genomic expression library, random peptide expression library or a chemically synthesized random peptide library, or non-peptide library. Expression libraries are introduced into the cells in which the assay occurs, where the nucleic acids of the library are expressed to produce their encoded proteins.

In one embodiment, peptide libraries that can be used in the present invention may be  
25 libraries that are chemically synthesized *in vitro*. Examples of such libraries are given in Houghten et al., 1991, Nature 354:84-86, which describes mixtures of free hexapeptides in which the first and second residues in each peptide were individually and specifically defined; Lam et al., 1991, Nature 354:82-84, which describes a "one bead, one peptide" approach in which a solid phase split synthesis scheme produced a library of peptides in which each bead in  
30 the collection had immobilized thereon a single, random sequence of amino acid residues; Medynski, 1994, Bio/Technology 12:709-710, which describes split synthesis and T-bag synthesis methods; and Gallop et al., 1994, J. Medicinal Chemistry 37(9):1233-1251. Simply by way of other examples, a combinatorial library may be prepared for use, according to the methods of Ohlmeyer et al., 1993, Proc. Natl. Acad. Sci. USA 90:10922-10926; Erb et al., 1994,

Proc. Natl. Acad. Sci. USA 91:11422-11426; Houghten et al., 1992, Biotechniques 13:412; Jayawickreme et al., 1994, Proc. Natl. Acad. Sci. USA 91:1614-1618; or Salmon et al., 1993, Proc. Natl. Acad. Sci. USA 90:11708-11712. PCT Publication No. WO 93/20242 and Brenner and Lerner, 1992, Proc. Natl. Acad. Sci. USA 89:5381-5383 describe "encoded combinatorial  
5 chemical libraries," that contain oligonucleotide identifiers for each chemical polymer library member.

In a preferred embodiment, the library screened is a biological expression library that is a random peptide phage display library, where the random peptides are constrained (*e.g.*, by virtue of having disulfide bonding).

10 Further, more general, structurally constrained, organic diversity (*e.g.*, nonpeptide) libraries, can also be used.

Conformationally constrained libraries that can be used include but are not limited to those containing invariant cysteine residues which, in an oxidizing environment, cross-link by disulfide bonds to form cystines, modified peptides (*e.g.*, incorporating fluorine, metals, isotopic  
15 labels, are phosphorylated, etc.), peptides containing one or more non-naturally occurring amino acids, non-peptide structures, and peptides containing a significant fraction of  $\gamma$ -carboxyglutamic acid.

Libraries of non-peptides, *e.g.*, peptide derivatives (for example, that contain one or more non-naturally occurring amino acids) can also be used. One example of these are peptoid  
20 libraries (Simon et al., 1992, Proc. Natl. Acad. Sci. USA 89:9367-9371). Peptoids are polymers of non-natural amino acids that have naturally occurring side chains attached not to the alpha carbon but to the backbone amino nitrogen. Since peptoids are not easily degraded by human digestive enzymes, they are advantageously more easily adaptable to drug use. Another example of a library that can be used, in which the amide functionalities in peptides have been  
25 permethylated to generate a chemically transformed combinatorial library, is described by Ostresh et al., 1994, Proc. Natl. Acad. Sci. USA 91:11138-11142).

The members of the peptide libraries that can be screened according to the invention are not limited to containing the 20 naturally occurring amino acids. In particular, chemically synthesized libraries and polysome based libraries allow the use of amino acids in addition to the  
30 20 naturally occurring amino acids (by their inclusion in the precursor pool of amino acids used in library production). In specific embodiments, the library members contain one or more non-natural or non-classical amino acids or cyclic peptides. Non-classical amino acids include but are not limited to the D-isomers of the common amino acids,  $\alpha$ -amino isobutyric acid, 4-aminobutyric acid, Abu, 2-amino butyric acid;  $\gamma$ -Abu,  $\epsilon$ -Ahx, 6-amino hexanoic acid; Aib, 2-

amino isobutyric acid; 3-amino propionic acid; ornithine; norleucine; norvaline, hydroxyproline, sarcosine, citrulline, cysteic acid, t-butylglycine, t-butylalanine, phenylglycine, cyclohexylalanine,  $\beta$ -alanine, designer amino acids such as  $\beta$ -methyl amino acids,  $C\alpha$ -methyl amino acids,  $N\alpha$ -methyl amino acids, fluoro-amino acids and amino acid analogs in general.

5 Furthermore, the amino acid can be D (dextrorotary) or L (levorotary).

In a specific embodiment, fragments and/or analogs of complexes of the invention, or protein components thereof, especially peptidomimetics, are screened for activity as competitive or non-competitive inhibitors of complex activity or formation.

In another embodiment of the present invention, combinatorial chemistry can be used to  
10 identify modulators of a the complexes. Combinatorial chemistry is capable of creating libraries containing hundreds of thousands of compounds, many of which may be structurally similar. While high throughput screening programs are capable of screening these vast libraries for affinity for known targets, new approaches have been developed that achieve libraries of smaller dimension but which provide maximum chemical diversity. (See, *e.g.*, Matter, 1997, Journal of  
15 Medicinal Chemistry 40:1219-1229).

One method of combinatorial chemistry, affinity fingerprinting, has previously been used to test a discrete library of small molecules for binding affinities for a defined panel of proteins. The fingerprints obtained by the screen are used to predict the affinity of the individual library members for other proteins or receptors of interest (in the instant invention, the protein  
20 complexes of the present invention and protein components thereof.) The fingerprints are compared with fingerprints obtained from other compounds known to react with the protein of interest to predict whether the library compound might similarly react. For example, rather than testing every ligand in a large library for interaction with a complex or protein component, only those ligands having a fingerprint similar to other compounds known to have that activity could  
25 be tested. (See, *e.g.*, Kauvar et al., 1995, Chemistry and Biology 2:107-118; Kauvar, 1995, Affinity fingerprinting, Pharmaceutical Manufacturing International. 8:25-28; and Kauvar, Toxic-Chemical Detection by Pattern Recognition in New Frontiers in Agrochemical Immunoassay, D. Kurtz. L. Stanker and J.H. Skerritt. Editors, 1995, AOAC: Washington, D.C., 305-312).

30 Kay et al., 1993, Gene 128:59-65 (Kay) discloses a method of constructing peptide libraries that encode peptides of totally random sequence that are longer than those of any prior conventional libraries. The libraries disclosed in Kay encode totally synthetic random peptides of greater than about 20 amino acids in length. Such libraries can be advantageously screened to



identify complex modulators. (See also U.S. Patent No. 5,498,538 dated March 12, 1996; and PCT Publication No. WO 94/18318 dated August 18, 1994).

A comprehensive review of various types of peptide libraries can be found in Gallop et al., 1994, J. Med. Chem. 37:1233-1251.

5 Libraries screened using the methods of the present invention can comprise a variety of types of compounds. Examples of libraries that can be screened in accordance with the methods of the invention include, but are not limited to, peptoids; random biooligomers; diversomers such as hydantoins, benzodiazepines and dipeptides; vinylogous polypeptides; nonpeptidal peptidomimetics; oligocarbamates; peptidyl phosphonates; peptide nucleic acid libraries;  
10 antibody libraries; carbohydrate libraries; and small molecule libraries (preferably, small organic molecule libraries). In some embodiments, the compounds in the libraries screened are nucleic acid or peptide molecules. In a non-limiting example, peptide molecules can exist in a phage display library. In other embodiments, the types of compounds include, but are not limited to, peptide analogs including peptides comprising non-naturally occurring amino acids, *e.g.*, D-  
15 amino acids, phosphorous analogs of amino acids, such as  $\alpha$ -amino phosphoric acids and  $\alpha$ -amino phosphoric acids, or amino acids having non-peptide linkages, nucleic acid analogs such as phosphorothioates and PNAs, hormones, antigens, synthetic or naturally occurring drugs, opiates, dopamine, serotonin, catecholamines, thrombin, acetylcholine, prostaglandins, organic molecules, pheromones, adenosine, sucrose, glucose, lactose and galactose. Libraries of  
20 polypeptides or proteins can also be used in the assays of the invention.

In a preferred embodiment, the combinatorial libraries are small organic molecule libraries including, but not limited to, benzodiazepines, isoprenoids, thiazolidinones, metathiazanones, pyrrolidines, morpholino compounds, and benzodiazepines. In another  
25 embodiment, the combinatorial libraries comprise peptoids; random bio-oligomers; benzodiazepines; diversomers such as hydantoins, benzodiazepines and dipeptides; vinylogous polypeptides; nonpeptidal peptidomimetics; oligocarbamates; peptidyl phosphonates; peptide nucleic acid libraries; antibody libraries; or carbohydrate libraries. Combinatorial libraries are themselves commercially available (see, *e.g.*, ComGenex, Princeton, New Jersey; Asinex,  
Moscow, Ru, Tripos, Inc., St. Louis, Missouri; ChemStar, Ltd, Moscow, Russia; 3D  
30 Pharmaceuticals, Exton, Pennsylvania; Martek Biosciences, Columbia, Maryland; *etc.*).

In a preferred embodiment, the library is preselected so that the compounds of the library are more amenable for cellular uptake. For example, compounds are selected based on specific parameters such as, but not limited to, size, lipophilicity, hydrophilicity, and hydrogen bonding, which enhance the likelihood of compounds getting into the cells. In another embodiment, the

compounds are analyzed by three-dimensional or four-dimensional computer computation programs.

The combinatorial compound library for use in accordance with the methods of the present invention may be synthesized. There is a great interest in synthetic methods directed toward the creation of large collections of small organic compounds, or libraries, which could be screened for pharmacological, biological or other activity. The synthetic methods applied to create vast combinatorial libraries are performed in solution or in the solid phase, *i.e.*, on a solid support. Solid-phase synthesis makes it easier to conduct multi-step reactions and to drive reactions to completion with high yields because excess reagents can be easily added and washed away after each reaction step. Solid-phase combinatorial synthesis also tends to improve isolation, purification and screening. However, the more traditional solution phase chemistry supports a wider variety of organic reactions than solid-phase chemistry.

Combinatorial compound libraries of the present invention may be synthesized using the apparatus described in U.S. Patent No. 6,190,619 to Kilcoin et al., which is hereby incorporated by reference in its entirety. U.S. Patent No. 6,190,619 discloses a synthesis apparatus capable of holding a plurality of reaction vessels for parallel synthesis of multiple discrete compounds or for combinatorial libraries of compounds.

In one embodiment, the combinatorial compound library can be synthesized in solution. The method disclosed in U.S. Patent No. 6,194,612 to Boger et al., which is hereby incorporated by reference in its entirety, features compounds useful as templates for solution phase synthesis of combinatorial libraries. The template is designed to permit reaction products to be easily purified from unreacted reactants using liquid/liquid or solid/liquid extractions. The compounds produced by combinatorial synthesis using the template will preferably be small organic molecules. Some compounds in the library may mimic the effects of non-peptides or peptides. In contrast to solid phase synthesis of combinatorial compound libraries, liquid phase synthesis does not require the use of specialized protocols for monitoring the individual steps of a multistep solid phase synthesis (Egner et al., 1995, J. Org. Chem. 60:2652; Anderson et al., 1995, J. Org. Chem. 60:2650; Fitch et al., 1994, J. Org. Chem. 59:7955; Look et al., 1994, J. Org. Chem. 49:7588; Metzger et al., 1993, Angew. Chem., Int. Ed. Engl. 32:894; Youngquist et al., 1994, Rapid Commun. Mass Spect. 8:77; Chu et al., 1995, J. Am. Chem. Soc. 117:5419; Brummel et al., 1994, Science 264:399; and Stevanovic et al., 1993, Bioorg. Med. Chem. Lett. 3:431).

Combinatorial compound libraries useful for the methods of the present invention can be synthesized on solid supports. In one embodiment, a split synthesis method, a protocol of

separating and mixing solid supports during the synthesis, is used to synthesize a library of compounds on solid supports (see *e.g.*, Lam et al., 1997, Chem. Rev. 97:41-448; Ohlmeyer et al., 1993, Proc. Natl. Acad. Sci. USA 90:10922-10926 and references cited therein). Each solid support in the final library has substantially one type of compound attached to its surface. Other methods for synthesizing combinatorial libraries on solid supports, wherein one product is attached to each support, will be known to those of skill in the art (see, *e.g.*, Nefzi et al., 1997, Chem. Rev. 97:449-472).

As used herein, the term "solid support" is not limited to a specific type of solid support. Rather a large number of supports are available and are known to one skilled in the art. Solid supports include silica gels, resins, derivatized plastic films, glass beads, cotton, plastic beads, polystyrene beads, alumina gels, and polysaccharides. A suitable solid support may be selected on the basis of desired end use and suitability for various synthetic protocols. For example, for peptide synthesis, a solid support can be a resin such as p-methylbenzhydrylamine (pMBHA) resin (Peptides International, Louisville, KY), polystyrenes (*e.g.*, PAM-resin obtained from Bachem Inc., Peninsula Laboratories, etc.), including chloromethylpolystyrene, hydroxymethylpolystyrene and aminomethylpolystyrene, poly (dimethylacrylamide)-grafted styrene co-divinyl-benzene (*e.g.*, POLYHIPE resin, obtained from Aminotech, Canada), polyamide resin (obtained from Peninsula Laboratories), polystyrene resin grafted with polyethylene glycol (*e.g.*, TENTAGEL or ARGOGEL, Bayer, Tübingen, Germany) polydimethylacrylamide resin (obtained from Milligen/Bioscience, California), or Sepharose (Pharmacia, Sweden).

In some embodiments of the present invention, compounds can be attached to solid supports via linkers. Linkers can be integral and part of the solid support, or they may be nonintegral that are either synthesized on the solid support or attached thereto after synthesis. Linkers are useful not only for providing points of compound attachment to the solid support, but also for allowing different groups of molecules to be cleaved from the solid support under different conditions, depending on the nature of the linker. For example, linkers can be, *inter alia*, electrophilically cleaved, nucleophilically cleaved, photocleavable, enzymatically cleaved, cleaved by metals, cleaved under reductive conditions or cleaved under oxidative conditions. In a preferred embodiment, the compounds are cleaved from the solid support prior to high throughput screening of the compounds.

In certain embodiments of the invention, the compound is a small molecule.

#### 4.5.13 Characterization of the Structure of Compounds

If the library comprises arrays or microarrays of compounds, wherein each compound has an address or identifier, the compound can be deconvoluted, *e.g.*, by cross-referencing the positive sample to original compound list that was applied to the individual test assays.

5 If the library is a peptide or nucleic acid library, the sequence of the compound can be determined by direct sequencing of the peptide or nucleic acid. Such methods are well known to one of skill in the art.

A number of physico-chemical techniques can be used for the *de novo* characterization of compounds identified by the screening methods of the invention. Examples of such  
10 techniques include, but are not limited to, mass spectrometry, NMR spectroscopy, X-ray crystallography and vibrational spectroscopy.

##### 4.5.13.1 MASS SPECTROMETRY

Mass spectrometry (*e.g.*, electrospray ionization ("ESI"), matrix-assisted laser desorption-ionization ("MALDI"), and Fourier-transformation cyclotron resonance ("FT-ICR"))  
15 can be used for elucidating the structure of a compound.

ESI mass spectrometry ("ESI-MS") has been of greater utility for studying non-covalent molecular interactions because, unlike the MALDI process, ESI-MS generates molecular ions with little to no fragmentation (Xavier et al., 2000, Trends Biotechnol. 18(8):349-356). ESI-MS has been used to study the complexes formed by HIV Tat peptide and protein with the TAR  
20 RNA (Sannes-Lowery et al., 1997, Anal. Chem. 69:5130-5135).

Fourier-transformation cyclotron resonance ("FT-ICR") mass spectrometry provides high-resolution spectra, isotope-resolved precursor ion selection, and accurate mass assignments (Xavier et al., 2000, Trends Biotechnol. 18(8):349-356). FT-ICR has been used to study the interaction of aminoglycoside antibiotics with cognate and non-cognate RNAs (Hofstadler *et al.*,  
25 1999, Anal. Chem. 71:3436-3440; and Griffey *et al.*, 1999, Proc. Natl. Acad. Sci. USA 96:10129-10133). As true for all of the mass spectrometry methods discussed herein, FT-ICR does not require labeling a compound.

##### 4.5.13.2 NMR Spectroscopy

30 NMR spectroscopy is a valuable technique for determining the structure of a compound by qualitatively determining changes in chemical shift, specifically from distances measured using relaxation effects. SAR by NMR can be used to elucidate the structure of a compound.

Examples of NMR that can be used for the invention include, but are not limited to, one-dimensional NMR, two-dimensional NMR, correlation spectroscopy ("COSY"), and nuclear Overhauser effect ("NOE") spectroscopy. Such methods of structure determination of compounds are well-known to one of skill in the art.

5

#### **4.5.13.3 X ray Crystallography**

X-ray crystallography can be used to elucidate the structure of a compound. For a review of x-ray crystallography see, *e.g.*, Blundell et al. 2002, Nat Rev Drug Discov 1(1):45-54. The first step in x-ray crystallography is the formation of crystals. The formation of crystals  
10 begins with the preparation of highly purified and soluble samples. The conditions for crystallization is then determined by optimizing several solution variables known to induce nucleation, such as pH, ionic strength, temperature, and specific concentrations of organic additives, salts and detergent. Techniques for automating the crystallization process have been developed to automate the production of high-quality protein crystals. Once crystals have been  
15 formed, the crystals are harvested and prepared for data collection. The crystals are then analyzed by diffraction (such as multi-circle diffractometers, high-speed CCD detectors, and detector off-set). Generally, multiple crystals must be screened for structure determinations.

#### **4.5.13.4 Vibrational Spectroscopy**

Vibrational spectroscopy (*e.g.* infrared (IR) spectroscopy or Raman spectroscopy) can be  
20 used for elucidating the structure of a compound. Infrared spectroscopy measures the frequencies of infrared light (wavelengths from 100 to 10,000 nm) absorbed by the compound as a result of excitation of vibrational modes according to quantum mechanical selection rules which require that absorption of light cause a change in the electric dipole moment of the molecule. The infrared spectrum of any molecule is a unique pattern of absorption wavelengths  
25 of varying intensity that can be considered as a molecular fingerprint to identify any compound.

Infrared spectra can be measured in a scanning mode by measuring the absorption of individual frequencies of light, produced by a grating which separates frequencies from a mixed-frequency infrared light source, by the compound relative to a standard intensity (double-beam instrument) or pre-measured ('blank') intensity (single-beam instrument). In a  
30 preferred embodiment, infrared spectra are measured in a pulsed mode ("FT-IR") where a mixed beam, produced by an interferometer, of all infrared light frequencies is passed through or reflected off the compound. The resulting interferogram, which may or may not be added with

the resulting interferograms from subsequent pulses to increase the signal strength while averaging random noise in the electronic signal, is mathematically transformed into a spectrum using Fourier Transform or Fast Fourier Transform algorithms.

5 Raman spectroscopy measures the difference in frequency due to absorption of infrared frequencies of scattered visible or ultraviolet light relative to the incident beam. The incident monochromatic light beam, usually a single laser frequency, is not truly absorbed by the compound but interacts with the electric field transiently. Most of the light scattered off the sample will be unchanged (Rayleigh scattering) but a portion of the scatter light will have frequencies that are the sum or difference of the incident and molecular vibrational frequencies.

10 The selection rules for Raman (inelastic) scattering require a change in polarizability of the molecule. While some vibrational transitions are observable in both infrared and Raman spectrometry, must are observable only with one or the other technique. The Raman spectrum of any molecule is a unique pattern of absorption wavelengths of varying intensity that can be considered as a molecular fingerprint to identify any compound.

15 Raman spectra are measured by submitting monochromatic light to the sample, either passed through or preferably reflected off, filtering the Rayleigh scattered light, and detecting the frequency of the Raman scattered light. An improved Raman spectrometer is described in US Patent No. 5,786,893 to Fink et al., which is hereby incorporated by reference.

Vibrational microscopy can be measured in a spatially resolved fashion to address single  
20 beads by integration of a visible microscope and spectrometer. A microscopic infrared spectrometer is described in U.S. Patent No. 5,581,085 to Reffner et al., which is hereby incorporated by reference in its entirety. An instrument that simultaneously performs a microscopic infrared and microscopic Raman analysis on a sample is described in U.S. Patent No. 5,841,139 to Sostek et al., which is hereby incorporated by reference in its entirety.

#### 25 **4.6 Secondary Assays**

The compounds identified in the assays described *supra* that modulate the activity or stability of a pre-tRNA splicing endonuclease, a 3' end pre-mRNA endonuclease, a pre-tRNA cleavage complex, rRNA endonuclease or a pre-rRNA cleavage complex (for convenience referred to herein as a "lead" compound) can be further tested for both direct binding to RNA  
30 and biological activity. In one embodiment, the compounds are tested for biological activity in further assays and/or animal models. In another embodiment, the lead compound is used to design congeners or analogs. In another embodiment, mutagenesis studies can be conducted to assess the mechanism by which a lead compound is modulating the activity of a human pre-

tRNA splicing endonuclease, a human 3' end pre-mRNA endonuclease, a human pre-tRNA cleavage complex, rRNA endonuclease or a human pre-rRNA cleavage complex. In yet another embodiment, a lead compound is tested for its ability to affect wound healing in a model system.

#### 5            **4.6.1 Phenotypic or Physiological Readout**

The compounds identified in the assays described *supra* (for convenience referred to herein as a "lead" compound) can be tested for biological activity using host cells containing or engineered to contain a human tRNA splicing endonuclease or a 3' end pre-mRNA endonuclease coupled to a functional readout system.

10            In one embodiment, the effect of a lead compound can be assayed by measuring the cell growth or viability of the target cell. Such assays can be carried out with representative cells of cell types involved in a particular proliferative disorder. A lower level of proliferation or survival of the contacted cells indicates that the lead compound is effective to treat a condition in the patient characterized by uncontrolled cell growth. Alternatively, instead of culturing cells  
15            from a patient, a lead compound may be screened using cells of a tumor or malignant cell line or an endothelial cell line. Specific examples of cell culture models include, but are not limited to, for lung cancer, primary rat lung tumor cells (Swafford et al., 1997, Mol. Cell. Biol., 17:1366-1374) and large-cell undifferentiated cancer cell lines (Mabry et al., 1991, Cancer Cells, 3:53-58); colorectal cell lines for colon cancer (Park and Gazdar, 1996, J. Cell Biochem. Suppl. 24:131-141); multiple established cell lines for breast cancer (Hambly et al., 1997, Breast  
20            Cancer Res. Treat. 43:247-258; Gierthy et al., 1997, Chemosphere 34:1495-1505; Prasad and Church, 1997, Biochem. Biophys. Res. Commun. 232:14-19); a number of well-characterized cell models for prostate cancer (Webber et al., 1996, Prostate, Part 1, 29:386-394; Part 2, 30:58-64; and Part 3, 30:136-142; Boulikas, 1997, Anticancer Res. 17:1471-1505); for  
25            genitourinary cancers, continuous human bladder cancer cell lines (Ribeiro et al., 1997, Int. J. Radiat. Biol. 72:11-20); organ cultures of transitional cell carcinomas (Booth et al., 1997, Lab Invest. 76:843-857) and rat progression models (Vet et al., 1997, Biochim. Biophys Acta 1360:39-44); and established cell lines for leukemias and lymphomas (Drexler, 1994, Leuk. Res. 18:919-927, Tohyama, 1997, Int. J. Hematol. 65:309-317). More specific examples of cell lines  
30            include the cancer cell line Huh7 (human hepatocellular carcinoma cell line) and the cancer cell line Caco-2 (a colon-cancer cell line). In certain embodiments, the effect of a lead compound on the growth and/or viability of a cancerous cell of a transformed cell is compared to the effect of

such a compound on the growth and/or viability of non-cancerous, normal cells. Preferably, compounds that differentially affect the growth and/or viability of cancerous cells or transformed cells are chosen as anti-proliferative agents.

Many assays well-known in the art can be used to assess the survival and/or growth of a patient cell or cell line following exposure to a lead compound; for example, cell proliferation can be assayed by measuring Bromodeoxyuridine (BrdU) incorporation (see, *e.g.*, Hoshino et al., 1986, *Int. J. Cancer* 38, 369; Campana et al., 1988, *J. Immunol. Meth.* 107:79) or (<sup>3</sup>H)-thymidine incorporation (see, *e.g.*, Chen, J., 1996, *Oncogene* 13:1395-403; Jeoung, J., 1995, *J. Biol. Chem.* 270:18367-73), by direct cell count, by detecting changes in transcription, translation or activity of known genes such as proto-oncogenes (*e.g.*, *fos*, *myc*) or cell cycle markers (Rb, *cdc2*, cyclin A, D1, D2, D3, E, etc). The levels of such protein and mRNA and activity can be determined by any method well known in the art. For example, protein can be quantitated by known immunodiagnostic methods such as Western blotting or immunoprecipitation using commercially available antibodies. mRNA can be quantitated using methods that are well known and routine in the art, for example, using northern analysis, RNase protection, the polymerase chain reaction in connection with the reverse transcription. Cell viability can be assessed by using trypan-blue staining or other cell death or viability markers known in the art. In a specific embodiment, the level of cellular ATP is measured to determine cell viability. Differentiation can be assessed, for example, visually based on changes in morphology.

The lead compound can also be assessed for its ability to inhibit cell transformation (or progression to malignant phenotype) *in vitro*. In this embodiment, cells with a transformed cell phenotype are contacted with a lead compound, and examined for change in characteristics associated with a transformed phenotype (a set of *in vitro* characteristics associated with a tumorigenic ability *in vivo*), for example, but not limited to, colony formation in soft agar, a more rounded cell morphology, looser substratum attachment, loss of contact inhibition, loss of anchorage dependence, release of proteases such as plasminogen activator, increased sugar transport, decreased serum requirement, or expression of fetal antigens, etc. (see Luria et al., 1978, *General Virology*, 3d Ed., John Wiley & Sons, New York, pp. 436-446).

Loss of invasiveness or decreased adhesion can also be assessed to demonstrate the anti-cancer effects of a lead compound. For example, an aspect of the formation of a metastatic cancer is the ability of a precancerous or cancerous cell to detach from primary site of disease and establish a novel colony of growth at a secondary site. The ability of a cell to invade



peripheral sites reflects its potential for a cancerous state. Loss of invasiveness can be measured by a variety of techniques known in the art including, for example, induction of E-cadherin-mediated cell-cell adhesion. Such E-cadherin-mediated adhesion can result in phenotypic reversion and loss of invasiveness (Hordijk et al., 1997, Science 278:1464-66).

5           Loss of invasiveness can further be examined by inhibition of cell migration. A variety of 2-dimensional and 3-dimensional cellular matrices are commercially available (Calbiochem-Novabiochem Corp. San Diego, CA). Cell migration across or into a matrix can be examined using microscopy, time-lapsed photography or videography, or by any method in the art allowing measurement of cellular migration. In a related embodiment, loss of  
10           invasiveness is examined by response to hepatocyte growth factor (HGF). HGF-induced cell scattering is correlated with invasiveness of cells such as Madin-Darby canine kidney (MDCK) cells. This assay identifies a cell population that has lost cell scattering activity in response to HGF (Hordijk et al., 1997, Science 278:1464-66).

                  Alternatively, loss of invasiveness can be measured by cell migration through a  
15           chemotaxis chamber (Neuroprobe/ Precision Biochemicals Inc. Vancouver, BC). In such assay, a chemo-attractant agent is incubated on one side of the chamber (*e.g.*, the bottom chamber) and cells are plated on a filter separating the opposite side (*e.g.*, the top chamber). In order for cells to pass from the top chamber to the bottom chamber, the cells must actively migrate through small pores in the filter. Checkerboard analysis of the number of cells that have migrated can  
20           then be correlated with invasiveness (*see e.g.*, Ohnishi, T., 1993, Biochem. Biophys. Res. Commun.193:518-25).

                  In certain embodiments, a lead compound is tested for its effects, such as, but not limited to, cytotoxicity, altered gene expression, and altered morphology, on PBMCs (Peripheral Blood Mononuclear Cells).

25

#### **4.6.2 Animal Models**

                  The lead compounds identified in the assays described herein can be tested for biological activity using animal models for a proliferative disorder. These include animals engineered to contain a tRNA splicing endonuclease or a 3' end pre-mRNA endonuclease coupled to a  
30           functional readout system, such as a transgenic mouse. Such animal model systems include, but are not limited to, rats, mice, chicken, cows, monkeys, pigs, dogs, rabbits, etc. In a specific embodiment of the invention, a compound identified in accordance with the methods of the

invention is tested in a mouse model system. Such model systems are widely used and well-known to the skilled artisan such as the SCID mouse model or transgenic mice.

The anti-angiogenic activity of a compound identified in accordance with the invention can be determined by using various experimental animal models of vascularized tumors. The anti-tumor activity of a compound identified in accordance with the invention can be determined by administering the compound to an animal model and verifying that the compound is effective in reducing the proliferation or spread of cancer cells in said animal model. An example of an animal model for human cancer in general includes, but is not limited to, spontaneously occurring tumors of companion animals (see, *e.g.*, Vail & MacEwen, 2000, *Cancer Invest* 18(8):781-92).

Examples of animal models for lung cancer include, but are not limited to, lung cancer animal models described by Zhang & Roth (1994, *In Vivo* 8(5):755-69) and a transgenic mouse model with disrupted p53 function (see, *e.g.*, Morris *et al.*, 1998, *J La State Med Soc* 150(4):179-85). An example of an animal model for breast cancer includes, but is not limited to, a transgenic mouse that overexpresses cyclin D1 (see, *e.g.*, Hosokawa *et al.*, 2001, *Transgenic Res* 10(5):471-8). An example of an animal model for colon cancer includes, but is not limited to, a TCRbeta and p53 double knockout mouse (see, *e.g.*, Kado *et al.*, 2001, *Cancer Res* 61(6):2395-8). Examples of animal models for pancreatic cancer include, but are not limited to, a metastatic model of Panc02 murine pancreatic adenocarcinoma (see, *e.g.*, Wang *et al.*, 2001, *Int J Pancreatol* 29(1):37-46) and nu-nu mice generated in subcutaneous pancreatic tumours (see, *e.g.*, Ghaneh *et al.*, 2001, *Gene Ther* 8(3):199-208). Examples of animal models for non-Hodgkin's lymphoma include, but are not limited to, a severe combined immunodeficiency ("SCID") mouse (see, *e.g.*, Bryant *et al.*, 2000, *Lab Invest* 80(4):553-73) and an IgHmu-HOX11 transgenic mouse (see, *e.g.*, Hough *et al.*, 1998, *Proc Natl Acad Sci USA* 95(23):13853-8). An example of an animal model for esophageal cancer includes, but is not limited to, a mouse transgenic for the human papillomavirus type 16 E7 oncogene (see, *e.g.*, Herber *et al.*, 1996, *J Virol* 70(3):1873-81). Examples of animal models for colorectal carcinomas include, but are not limited to, Apc mouse models (see, *e.g.*, Fodde & Smits, 2001, *Trends Mol Med* 7(8):369-73 and Kuraguchi *et al.*, 2000, *Oncogene* 19(50):5755-63).

In certain embodiments, the animal model is a model system for vascular wound healing, for degenerated, leisedured or insured tissue. Models for wound healing include sores, lesions, ulcers and bedsores. The lead compounds of the invention can be tested for their ability to facilitate, promote and/or enhance the process of wound healing.

#### 4.6.3 Toxicity

The toxicity and/or efficacy of a compound identified in accordance with the invention can be determined by standard pharmaceutical procedures in cell cultures or experimental animals, *e.g.*, for determining the LD<sub>50</sub> (the dose lethal to 50% of the population) and the ED<sub>50</sub> (the dose therapeutically effective in 50% of the population). Cells and cell lines that can be used to assess the cytotoxicity of a compound identified in accordance with the invention include, but are not limited to, peripheral blood mononuclear cells (PBMCs), Caco-2 cells, and Huh7 cells. The dose ratio between toxic and therapeutic effects is the therapeutic index and it can be expressed as the ratio LD<sub>50</sub>/ED<sub>50</sub>. A compound identified in accordance with the invention that exhibits large therapeutic indices is preferred. While a compound identified in accordance with the invention that exhibits toxic side effects may be used, care should be taken to design a delivery system that targets such agents to the site of affected tissue in order to minimize potential damage to uninfected cells and, thereby, reduce side effects.

The data obtained from the cell culture assays and animal studies can be used in formulating a range of dosage of a compound identified in accordance with the invention for use in humans. The dosage of such agents lies preferably within a range of circulating concentrations that include the ED<sub>50</sub> with little or no toxicity. The dosage may vary within this range depending upon the dosage form employed and the route of administration utilized. For any agent used in the method of the invention, the therapeutically effective dose can be estimated initially from cell culture assays. A dose may be formulated in animal models to achieve a circulating plasma concentration range that includes the IC<sub>50</sub> (*i.e.*, the concentration of the compound that achieves a half-maximal inhibition of symptoms) as determined in cell culture. Such information can be used to more accurately determine useful doses in humans. Levels in plasma may be measured, for example, by high performance liquid chromatography.

#### 4.6.4 Design of Congeners or Analogs

The compounds which display the desired biological activity can be used as lead compounds for the development or design of congeners or analogs having useful pharmacological activity. For example, once a lead compound is identified, molecular modeling techniques can be used to design variants of the compound that can be more effective. Examples of molecular modeling systems are the CHARM and QUANTA programs (Polygen

Corporation, Waltham, MA). CHARM performs the energy minimization and molecular dynamics functions. QUANTA performs the construction, graphic modelling and analysis of molecular structure. QUANTA allows interactive construction, modification, visualization, and analysis of the behavior of molecules with each other.

5           A number of articles review computer modeling of drugs interactive with specific proteins, such as Rotivinen et al., 1988, Acta Pharmaceutical Fennica 97:159-166; Ripka, 1998, New Scientist 54-57; McKinaly & Rossmann, 1989, Annu. Rev. Pharmacol. Toxiciol. 29:111-122; Perry & Davies, OSAR: Quantitative Structure-Activity Relationships in Drug Design pp. 189-193 (Alan R. Liss, Inc. 1989); Lewis & Dean, 1989, Proc. R. Soc. Lond. 236:125-140  
10       and 141-162; Askew et al., 1989, J. Am. Chem. Soc. 111:1082-1090. Other computer programs that screen and graphically depict chemicals are available from companies such as BioDesign, Inc. (Pasadena, California), Allelix, Inc. (Mississauga, Ontario, Canada), and Hypercube, Inc. (Cambridge, Ontario). Although these are primarily designed for application to drugs specific to particular proteins, they can be adapted to design of drugs specific to any identified region. The  
15       analog and congeners can be tested for binding to a human tRNA splicing endonuclease using the above-described screens for biologic activity. Alternatively, lead compounds with little or no biologic activity, as ascertained in the screen, can also be used to design analogs and congeners of the compound that have biologic activity.

#### 20           4.7 Pharmaceutical Compositions of the Invention

          In certain embodiments, the invention provides compositions comprising a carrier and one the following or a combination of two or more of the following: (i) a component of a complex of the invention (*e.g.*, human Sen2, human Sen15, human Sen34, human Sen54, human Sen2deltaEx8, or functionally active derivatives of functionally active fragments thereof; (ii) a  
25       complex of the invention, (iii) an antibody or a fragment thereof that immunospecifically binds to a component of a complex of the invention, or a complex of the invention, (iv) a compound that modulates the expression of a component of a complex of the invention, (v) a compound that modulates the formation of a complex of the invention, (vi) a compound that modulates the endonuclease activity (*e.g.*, tRNA splicing endonuclease activity and/or 3' end pre-mRNA  
30       endonuclease activity) of a complex of the invention, (vii) a compound that modulates the pre-tRNA cleavage activity of a complex of the invention, and/or (viii) a compound that modulates pre-ribosomal RNA cleavage activity of a complex of the invention. The compositions may

further comprise one or more other prophylactic or therapeutic agents. In a preferred embodiment, the compositions are pharmaceutical compositions. In accordance with this embodiment, the pharmaceutical compositions are preferably sterile and in suitable form for the intended method of administration or use. The invention encompasses the use of the  
5 compositions of the invention in the prevention, treatment, management or amelioration of a disorder described herein or a symptom thereof.

In certain embodiments of the invention, a pharmaceutical composition of the invention comprises Sen2, Clp1, Sen54, Sen15, and Sen34. In certain embodiments of the invention, a pharmaceutical composition of the invention comprises Sen2, Sen54, Sen15, and Sen34. In  
10 certain embodiments of the invention, a pharmaceutical composition of the invention comprises Sen2deltaEx8. In certain embodiments of the invention, a pharmaceutical composition of the invention comprises Sen2deltaEx8 and Sen54. In certain embodiments of the invention, a pharmaceutical composition of the invention comprises Sen2deltaEx8, Sen54, Sen15 and Sen34. In accordance with these embodiments, a pharmaceutical composition of the invention may  
15 further comprise: (i) human CPSF160; (ii) human CPSF30; (iii) human CstF64; and/or (iv) human symplekin.

The different protein components can be present in the form of a complex or not in the form of a complex. In other embodiments, a pharmaceutical composition comprises Sen2, Clp1, Sen54, Sen15, Sen34, CPSF, CFIm, CFIIIm and CstF. The different protein components can be  
20 present in the form of a complex or not in the form of a complex. In even other embodiments, a pharmaceutical composition comprises Sen2deltaEx8, Clp1, Sen54, Sen15, Sen34, CPSF, CFIm, CFIIIm and CstF. The different protein components can be present in the form of a complex or not in the form of a complex.

In even other embodiments, a pharmaceutical composition comprises an antibody that  
25 binds specifically to Sen2deltaEx8. In even more specific embodiments, the antibody does not bind to Sen2. In yet other embodiments, a pharmaceutical composition comprises an oligonucleotide that hybridizes specifically to a nucleic acid encoding Sen2deltaEx8.

In even other embodiments, a pharmaceutical composition comprises an antibody that binds specifically to a component of a complex of the invention. In yet other embodiments, a  
30 pharmaceutical composition comprises an oligonucleotide that hybridizes specifically to a nucleic acid encoding a component of a complex of the invention. In even other embodiments, a pharmaceutical composition comprises an antibody that binds immunospecifically to a complex of the invention. In a more specific embodiments, the antibody does not bind to an individual

component of a complex of the invention.

In certain embodiments, a pharmaceutical composition of the invention also comprises a pharmaceutically acceptable carrier.

The compositions of the invention include, but are not limited to, bulk drug compositions  
5 useful in the manufacture of pharmaceutical compositions (*e.g.*, impure or non-sterile compositions) and pharmaceutical compositions (*i.e.*, compositions that are suitable for administration to a subject or patient) which can be used in the preparation of unit dosage forms. Such compositions comprise a prophylactically or therapeutically effective amount of a prophylactic and/or therapeutic agent disclosed herein or a combination of those agents and a  
10 pharmaceutically acceptable carrier.

In a specific embodiment, the term "pharmaceutically acceptable" means approved by a regulatory agency of the Federal or a state government or listed in the U.S. Pharmacopeia or other generally recognized pharmacopeia for use in animals, and more particularly in humans. The term "carrier" refers to a diluent, adjuvant (*e.g.*, Freund's adjuvant (complete and  
15 incomplete)), excipient, or vehicle with which the therapeutic is contained in or administered. Such pharmaceutical carriers can be sterile liquids, such as water and oils, including those of petroleum, animal, vegetable or synthetic origin, such as peanut oil, soybean oil, mineral oil, sesame oil and the like. Water is a preferred carrier when the pharmaceutical composition is administered intravenously. Saline solutions and aqueous dextrose and glycerol solutions can  
20 also be employed as liquid carriers, particularly for injectable solutions. Suitable pharmaceutical excipients include starch, glucose, lactose, sucrose, gelatin, malt, rice, flour, chalk, silica gel, sodium stearate, glycerol monostearate, talc, sodium chloride, dried skim milk, glycerol, propylene, glycol, water, ethanol and the like. The composition, if desired, can also contain minor amounts of wetting or emulsifying agents, or pH buffering agents. These  
25 compositions can take the form of solutions, suspensions, emulsion, tablets, pills, capsules, powders, sustained-release formulations and the like.

Generally, the ingredients of compositions of the invention are supplied either separately or mixed together in unit dosage form, for example, as a dry lyophilized powder or water free concentrate in a hermetically sealed container such as an ampoule or sachette indicating the  
30 quantity of active agent. Where the composition is to be administered by infusion, it can be dispensed with an infusion bottle containing sterile pharmaceutical grade water or saline. Where the composition is administered by injection, an ampoule of sterile water for injection or saline can be provided so that the ingredients may be mixed prior to administration.

The compositions of the invention can be formulated as neutral or salt forms.

Pharmaceutically acceptable salts include those formed with anions such as those derived from hydrochloric, phosphoric, acetic, oxalic, tartaric acids, etc., and those formed with cations such as those derived from sodium, potassium, ammonium, calcium, ferric hydroxides, isopropylamine, triethylamine, 2-ethylamino ethanol, histidine, procaine, etc.

For routes of administration see section 4.9.

#### 4.8 Prophylactic and Therapeutic Uses

A compound identified in assays described herein that modulates the expression of a component of a complex of the invention, the formation of a complex of the invention, the RNA-nucleolytic activity of a complex of the invention (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention) may be tested in *in vitro* assays (*e.g.*, cell-based assays or cell-free assays) or *in vivo* assays well-known to one of skill in the art or described herein for the effect of the compound a disorder described herein (*e.g.*, a proliferative disorder or a disorder characterized by, associated with or caused by abnormal RNA-nucleolytic activity) or on cells from a patient with a particular disorder.

The present invention provides methods of preventing, treating, managing or ameliorating a proliferative disorder or a disorder characterized by, associated with or caused by abnormal RNA-nucleolytic activity or one or more symptoms thereof, said methods comprising administering to a subject in need thereof one or more compounds identified in accordance with the methods of the invention. In one embodiment, the invention provides a method of preventing, treating, managing or ameliorating a proliferative disorder or a disorder characterized by, associated with or caused by abnormal RNA-nucleolytic activity or one or more symptoms thereof, said method comprising administering to a subject in need thereof a dose of a prophylactically or therapeutically effective amount of one or more compounds identified in accordance with the methods of the invention. In another embodiment, a compound identified in accordance with the methods of the invention is not administered to prevent, treat, or ameliorate a proliferative disorder or a disorder characterized by, associated with or caused by abnormal RNA-nucleolytic activity or one or more symptoms thereof, if such compound has been used previously to prevent, treat, manage or ameliorate said proliferative

disorder. In a specific embodiment, a therapeutic method of the invention comprises administering an effective amount of a compound that has been identified using the methods of the invention as an antagonist of a pre-tRNA splicing endonuclease complex or a 3' end pre-mRNA endonuclease complex. An antagonist can be a compound that destabilizes the complex, prevents its formation or decreases its catalytic activity.

In certain other embodiments, a therapeutically effective amount of a compound identified using the methods of the invention as an agonist of 3' end pre-mRNA endonuclease or pre-tRNA splicing endonuclease is administered to promote wound healing. An agonist may act by stabilizing the complex or by activating the catalytic activity of the complex.

In certain embodiments, a therapeutic method of the invention comprises administering a pharmaceutically effective amount of two or more of the following: Sen2, Clp1, Sen54, Sen15, and Sen34. In certain embodiments, a therapeutic method of the invention comprises administering a pharmaceutically effective amount of Sen2, Clp1, Sen54, Sen15, and Sen34. In accordance with these embodiments, a pharmaceutical composition of the invention may further comprise: (i) human CPSF160; (ii) human CPSF30; (iii) human CstF64; and/or (iv) human symplekin. In other embodiments, a therapeutic method of the invention comprises administering a pharmaceutically effective amount of Sen2, Clp1, Sen54, Sen15, Sen34, CPSF, CFIm, CFIIIm and CstF. In other embodiments, a therapeutic method comprises administering Sen2 $\Delta$ Ex8 and optionally Sen15, Sen34, Sen54 and Clp1. In accordance with these embodiments, a pharmaceutical composition of the invention may further comprise: (i) human CPSF160; (ii) human CPSF30; (iii) human CstF64; and/or (iv) human symplekin. In even other embodiments, a therapeutic method of the invention comprises administering a pharmaceutically effective amount of Sen2 $\Delta$ Ex8, Clp1, Sen54, Sen15, Sen34, CPSF, CFIm, CFIIIm and CstF. The different protein components can be present in the form of a complex or not in the form of a complex.

In even other embodiments, a therapeutic method of the invention comprises administering a pharmaceutically effective amount of an antibody that binds specifically to Sen2 $\Delta$ Ex8. In even more specific embodiments, the antibody does not bind to Sen2.

In yet other embodiments, a therapeutic method of the invention comprises administering a pharmaceutically effective amount of an oligonucleotide that hybridizes specifically to a nucleic acid encoding Sen2 $\Delta$ Ex8.

The invention also provides methods of preventing, treating, managing or ameliorating a proliferative disorder or a disorder characterized by, associated with or caused by abnormal



RNA-nucleolytic activity (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention) or one or more symptoms thereof, said methods comprising administering to a subject in need thereof one or more of the compounds identified utilizing the screening methods described herein, and one or more other therapies (*e.g.*, prophylactic or therapeutic agents), which therapies are currently being used, have been used or are known to be useful in the prevention, treatment, management or amelioration of one or more symptoms associated with said proliferative disorder (including, but not limited to the prophylactic or therapeutic agents listed in Section 4.8.3 hereinbelow).

10 The therapies (*e.g.*, prophylactic or therapeutic agents) of the combination therapies of the invention can be administered sequentially or concurrently. In a specific embodiment, the combination therapies of the invention comprise a compound identified in accordance with the invention and at least one other therapy that has the same mechanism of action as said compound. In another specific embodiment, the combination therapies of the invention

15 comprise a compound identified in accordance with the methods of the invention and at least one other therapy (*e.g.*, prophylactic or therapeutic agent) which has a different mechanism of action than said compound. The combination therapies of the present invention improve the prophylactic or therapeutic effect of a compound of the invention by functioning together with the compound to have an additive or synergistic effect. The combination therapies of the

20 present invention reduce the side effects associated with the therapies (*e.g.*, prophylactic or therapeutic agents).

The prophylactic or therapeutic agents of the combination therapies can be administered to a subject in the same pharmaceutical composition. Alternatively, the prophylactic or therapeutic agents of the combination therapies can be administered concurrently to a subject in

25 separate pharmaceutical compositions. The prophylactic or therapeutic agents may be administered to a subject by the same or different routes of administration.

In specific embodiment, a pharmaceutical composition comprising one or more compounds identified in a screening assay described herein is administered to a subject, preferably a human, to prevent, treat, manage or ameliorate a proliferative disorder or one or

30 more symptoms thereof. In accordance with the invention, the pharmaceutical composition may also comprise one or more prophylactic or therapeutic agents which are currently being used, have been used or are known to be useful in the prevention, treatment, management or amelioration of a proliferative disorder or one or more symptoms thereof.

A compound identified in accordance with the methods of the invention may be used as a first, second, third, fourth or fifth line of therapy for a proliferative disorder or a disorder characterized by, associated with or caused by abnormal RNA-nucleolytic activity (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention). The invention provides methods for treating, managing or ameliorating a proliferative disorder or a disorder characterized by, associated with or caused by abnormal RNA-nucleolytic activity (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention) or one or more symptoms thereof in a subject refractory to conventional therapies for such proliferative disorder, said methods comprising administering to said subject a dose of a prophylactically or therapeutically effective amount of a compound identified in accordance with the methods of the invention. In particular, a cancer or a disorder characterized by, associated with or caused by abnormal RNA-nucleolytic activity (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention) may be determined to be refractory to a therapy means when at least some significant portion of the cancer cells or cells characterized by, associated with or caused by abnormal RNA-nucleolytic activity (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention) are not killed or their cell division arrested in response to the therapy. Such a determination can be made either *in vivo* or *in vitro* by any method known in the art for assaying the effectiveness of treatment on cancer cells, using the art-accepted meanings of "refractory" in such a context. In a specific embodiment, a cancer is refractory where the number of cancer cells has not been significantly reduced, or has increased.

In more specific embodiments, the invention provides methods for treating, managing or ameliorating one or more symptoms of a proliferative disorder in a subject refractory to existing single agent therapies for such proliferative disorder, said methods comprising administering to said subject a dose of a prophylactically or therapeutically effective amount of a compound identified in accordance with the methods of the invention and a dose of a prophylactically or therapeutically effective amount of one or more other therapies (*e.g.*, prophylactic or therapeutic

agents). The invention also provides methods for treating or managing a proliferative disorder by administering a compound identified in accordance with the methods of the invention in combination with any other therapy (*e.g.*, radiation therapy, chemotherapy or surgery) to patients who have proven refractory to other therapies but are no longer on these therapies. The invention also provides methods for the treatment or management of a patient having a proliferative disorder and immunosuppressed by reason of having previously undergone other therapies. The invention also provides alternative methods for the treatment or management of a proliferative disorder such as cancer where chemotherapy, radiation therapy, hormonal therapy, and/or biological therapy/immunotherapy has proven or may prove too toxic, *i.e.*, results in unacceptable or unbearable side effects, for the subject being treated or managed. Further, the invention provides methods for preventing the recurrence of a proliferative disorder such as cancer in patients that have been treated and have no disease activity by administering a compound identified in accordance with the methods of the invention.

Proliferative disorders that can be treated by the methods encompassed by the invention include, but are not limited to, neoplasms, tumors, metastases, or any disease or disorder characterized by uncontrolled cell growth (*e.g.*, psoriasis and pulmonary fibrosis). The cancer may be a primary or metastatic cancer.

Specific examples of cancers that can be treated by the methods encompassed by the invention include, but are not limited to, cancer of the head, neck, eye, mouth, throat, esophagus, chest, bone, lung, colon, rectum, stomach, prostate, breast, ovaries, kidney, liver, pancreas, and brain. Additional cancers include, but are not limited to, the following: leukemias such as but not limited to, acute leukemia, acute lymphocytic leukemia, acute myelocytic leukemias such as myeloblastic, promyelocytic, myelomonocytic, monocytic, erythroleukemia leukemias and myelodysplastic syndrome, chronic leukemias such as but not limited to, chronic myelocytic (granulocytic) leukemia, chronic lymphocytic leukemia, hairy cell leukemia; polycythemia vera; lymphomas such as but not limited to Hodgkin's disease, non-Hodgkin's disease; multiple myelomas such as but not limited to smoldering multiple myeloma, nonsecretory myeloma, osteosclerotic myeloma, plasma cell leukemia, solitary plasmacytoma and extramedullary plasmacytoma; Waldenström's macroglobulinemia; monoclonal gammopathy of undetermined significance; benign monoclonal gammopathy; heavy chain disease; bone and connective tissue sarcomas such as but not limited to bone sarcoma, osteosarcoma, chondrosarcoma, Ewing's sarcoma, malignant giant cell tumor, fibrosarcoma of bone, chordoma, periosteal sarcoma, soft-tissue sarcomas, angiosarcoma (hemangiosarcoma), fibrosarcoma, Kaposi's sarcoma,

leiomyosarcoma, liposarcoma, lymphangiosarcoma, neurilemmoma, rhabdomyosarcoma, synovial sarcoma; brain tumors such as but not limited to, glioma, astrocytoma, brain stem glioma, ependymoma, oligodendroglioma, nonglial tumor, acoustic neurinoma, craniopharyngioma, medulloblastoma, meningioma, pineocytoma, pineoblastoma, primary brain lymphoma; breast cancer including but not limited to adenocarcinoma, lobular (small cell) carcinoma, intraductal carcinoma, medullary breast cancer, mucinous breast cancer, tubular breast cancer, papillary breast cancer, Paget's disease, and inflammatory breast cancer; adrenal cancer such as but not limited to pheochromocytom and adrenocortical carcinoma; thyroid cancer such as but not limited to papillary or follicular thyroid cancer, medullary thyroid cancer and anaplastic thyroid cancer; pancreatic cancer such as but not limited to, insulinoma, gastrinoma, glucagonoma, vipoma, somatostatin-secreting tumor, and carcinoid or islet cell tumor; pituitary cancers such as but limited to Cushing's disease, prolactin-secreting tumor, acromegaly, and diabetes insipius; eye cancers such as but not limited to ocular melanoma such as iris melanoma, choroidal melanoma, and ciliary body melanoma, and retinoblastoma; vaginal cancers such as squamous cell carcinoma, adenocarcinoma, and melanoma; vulvar cancer such as squamous cell carcinoma, melanoma, adenocarcinoma, basal cell carcinoma, sarcoma, and Paget's disease; cervical cancers such as but not limited to, squamous cell carcinoma, and adenocarcinoma; uterine cancers such as but not limited to endometrial carcinoma and uterine sarcoma; ovarian cancers such as but not limited to, ovarian epithelial carcinoma, borderline tumor, germ cell tumor, and stromal tumor; esophageal cancers such as but not limited to, squamous cancer, adenocarcinoma, adenoid cystic carcinoma, mucoepidermoid carcinoma, adenosquamous carcinoma, sarcoma, melanoma, plasmacytoma, verrucous carcinoma, and oat cell (small cell) carcinoma; stomach cancers such as but not limited to, adenocarcinoma, fungating (polypoid), ulcerating, superficial spreading, diffusely spreading, malignant lymphoma, liposarcoma, fibrosarcoma, and carcinosarcoma; colon cancers; rectal cancers; liver cancers such as but not limited to hepatocellular carcinoma and hepatoblastoma, gallbladder cancers such as adenocarcinoma; cholangiocarcinomas such as but not limited to papillary, nodular, and diffuse; lung cancers such as non-small cell lung cancer, squamous cell carcinoma (epidermoid carcinoma), adenocarcinoma, large-cell carcinoma and small-cell lung cancer; testicular cancers such as but not limited to germinal tumor, seminoma, anaplastic, classic (typical), spermatocytic, nonseminoma, embryonal carcinoma, teratoma carcinoma, choriocarcinoma (yolk-sac tumor), prostate cancers such as but not limited to, adenocarcinoma, leiomyosarcoma, and rhabdomyosarcoma; penile cancers; oral cancers such as but not limited to

squamous cell carcinoma; basal cancers; salivary gland cancers such as but not limited to adenocarcinoma, mucoepidermoid carcinoma, and adenoidcystic carcinoma; pharynx cancers such as but not limited to squamous cell cancer, and verrucous; skin cancers such as but not limited to, basal cell carcinoma, squamous cell carcinoma and melanoma, superficial spreading melanoma, nodular melanoma, lentigo malignant melanoma, acral lentiginous melanoma; kidney cancers such as but not limited to renal cell cancer, adenocarcinoma, hypernephroma, fibrosarcoma, transitional cell cancer (renal pelvis and/or uterer); Wilms' tumor; bladder cancers such as but not limited to transitional cell carcinoma, squamous cell cancer, adenocarcinoma, carcinosarcoma. In addition, cancers include myxosarcoma, osteogenic sarcoma, endotheliosarcoma, lymphangioendotheliosarcoma, mesothelioma, synovioma, hemangioblastoma, epithelial carcinoma, cystadenocarcinoma, bronchogenic carcinoma, sweat gland carcinoma, sebaceous gland carcinoma, papillary carcinoma and papillary adenocarcinomas (for a review of such disorders, see Fishman et al., 1985, *Medicine*, 2d Ed., J.B. Lippincott Co., Philadelphia and Murphy et al., 1997, *Informed Decisions: The Complete Book of Cancer Diagnosis, Treatment, and Recovery*, Viking Penguin, Penguin Books U.S.A., Inc., United States of America). It is also contemplated that cancers caused by aberrations in apoptosis can also be treated by the methods and compositions of the invention. Such cancers may include, but not be limited to, follicular lymphomas, carcinomas with p53 mutations, hormone dependent tumors of the breast, prostate and ovary, and precancerous lesions such as familial adenomatous polyposis, and myelodysplastic syndromes.

Wounds that can be treated by the methods encompassed by the invention include, but are not limited to, sores, lesions, ulcers and bedsores.

#### **4.8.1 Use Of Antisense Oligonucleotides For Suppression Of Protein Complex Activity Or Formation**

In a specific embodiment of the present invention, the activity and formation of a complex of the invention is inhibited by use of antisense nucleic acids specific to a protein component of the complex that is up-regulated in a subject. The present invention provides the therapeutic or prophylactic use of nucleic acids of at least six nucleotides that are antisense to a gene or cDNA encoding a component protein, or a portion thereof. An "antisense" nucleic acid as used herein refers to a nucleic acid capable of hybridizing to a portion of a component protein RNA (preferably mRNA) by virtue of some sequence complementarity. The antisense nucleic acid may be complementary to a coding and/or noncoding region of a component protein

mRNA. Such antisense nucleic acids that inhibit complex formation or activity have utility as Therapeutics, and can be used in the treatment or prevention of disorders as described *supra*.

The antisense nucleic acids of the invention can be oligonucleotides that are double-stranded or single-stranded, RNA or DNA, or a modification or derivative thereof, which can be  
5 directly administered to a cell, or which can be produced intracellularly by transcription of exogenous, introduced sequences.

In another embodiment, the present invention is directed to a method for inhibiting the expression of component protein nucleic acid sequences, in a prokaryotic or eukaryotic cell, comprising providing the cell with an effective amount of a composition comprising an  
10 antisense nucleic acid of the component protein, or a derivative thereof, of the invention.

The antisense nucleic acids are of at least six nucleotides and are preferably oligonucleotides, ranging from 6 to about 200 nucleotides. In specific aspects, the oligonucleotide is at least 10 nucleotides, at least 15 nucleotides, at least 100 nucleotides, or at least 200 nucleotides. The oligonucleotides can be DNA or RNA or chimeric mixtures, or  
15 derivatives or modified versions thereof, and either single-stranded or double-stranded. The oligonucleotide can be modified at the base moiety, sugar moiety, or phosphate backbone. The oligonucleotide may include other appending groups such as peptides, agents facilitating transport across the cell membrane (see, *e.g.*, Letsinger et al., 1989, Proc. Natl. Acad. Sci. U.S.A. 86:6553-6556; Lemaitre et al., 1987, Proc. Natl. Acad. Sci. 84:648-652; International  
20 Patent Publication No. WO 88/09810) or blood-brain barrier (see, *e.g.*, International Patent Publication No. WO 89/10134), hybridization-triggered cleavage agents (see, *e.g.*, Krol et al., 1988, BioTechniques 6:958-976), or intercalating agents (see, *e.g.*, Zon, 1988, Pharm. Res. 5:539-549).

In a preferred aspect of the invention, an antisense oligonucleotide is provided,  
25 preferably as single-stranded DNA. The oligonucleotide may be modified at any position in its structure with constituents generally known in the art.

The antisense oligonucleotides may comprise at least one modified base moiety which is selected from the group including but not limited to 5-fluorouracil, 5-bromouracil, 5-chlorouracil, 5-iodouracil, hypoxanthine, xanthine, 4-acetylcytosine,  
30 5-(carboxyhydroxymethyl)uracil, 5-carboxymethylaminomethyl-2-thio-uridine, 5-carboxymethylaminomethyluracil, dihydrouracil, beta-D-galactosylqueosine, inosine, N6-isopentenyladenine, 1-methylguanine, 1-methylinosine, 2,2-dimethylguanine, 2-methyladenine, 2-methylguanine, 3-methylcytosine, 5-methylcytosine, N6-adenine, 7-methylguanine, 5-methylaminomethyluracil, 5-methoxyaminomethyl-2-thiouracil,

beta-D-mannosylqueosine, 5N-methoxycarboxymethyluracil, 5-methoxyuracil, 2-methyl-thio-N6-isopentenyladenine, uracil-5-oxyacetic acid (v), wybutoxosine, pseudouracil, queosine, 2-thiocytosine, 5-methyl-2-thiouracil, 2-thiouracil, 4-thiouracil, 5-methyluracil, uracil-5-oxyacetic acid methylester, uracil-5-oxyacetic acid (v), 5-methyl-2-thiouracil,  
5 3-(3-amino-3-N-2-carboxypropyl) uracil, (acp3)w, and 2,6-diaminopurine.

In another embodiment, the oligonucleotide comprises at least one modified sugar moiety selected from the group including, but not limited to, arabinose, 2-fluoroarabinose, xylulose, and hexose.

In yet another embodiment, the oligonucleotide comprises at least one modified  
10 phosphate backbone selected from the group consisting of a phosphorothioate, a phosphorodithioate, a phosphoramidothioate, a phosphoramidate, a phosphordiamidate, a methylphosphonate, an alkyl phosphotriester, and a formacetal, or an analog of the foregoing.

In yet another embodiment, the oligonucleotide is a 2'-anomeric oligonucleotide. An anomeric oligonucleotide forms specific double-stranded hybrids with complementary RNA in  
15 which, contrary to the usual  $\beta$ -units, the strands run parallel to each other (Gautier et al., 1987, Nucl. Acids Res. 15:6625-6641).

The oligonucleotide may be conjugated to another molecule, *e.g.*, a peptide, hybridization-triggered cross-linking agent, transport agent, hybridization-triggered cleavage agent, etc.

20 Oligonucleotides of the invention may be synthesized by standard methods known in the art, *e.g.*, by use of an automated DNA synthesizer (such as are commercially available from Biosearch, Applied Biosystems, etc.). As examples, phosphorothioate oligonucleotides may be synthesized by the method of Stein et al. (1988, Nucl. Acids Res. 16:3209), methylphosphonate oligonucleotides can be prepared by use of controlled pore glass polymer supports (Sarin et al.,  
25 1988, Proc. Natl. Acad. Sci. U.S.A. 85:7448-7451), etc.

In a specific embodiment, the antisense oligonucleotides comprise catalytic RNAs, or ribozymes (see, *e.g.*, International Patent Publication No. WO 90/11364; Sarver et al., 1990, Science 247:1222-1225). In another embodiment, the oligonucleotide is a 2'-O-methylribonucleotide (Inoue et al., 1987, Nucl. Acids Res. 15:6131-6148), or a chimeric RNA-  
30 DNA analog (Inoue et al., 1987, FEBS Lett. 215:327-330).

In an alternative embodiment, the antisense nucleic acids of the invention are produced intracellularly by transcription from an exogenous sequence. For example, a vector can be introduced in vivo such that it is taken up by a cell, within which cell the vector or a portion thereof is transcribed, producing an antisense nucleic acid (RNA) of the invention. Such a

vector would contain a sequence encoding the component protein. Such a vector can remain episomal or become chromosomally integrated, as long as it can be transcribed to produce the desired antisense RNA. Such vectors can be constructed by recombinant DNA technology methods standard in the art. Vectors can be plasmid, viral, or others known in the art to be capable of replication and expression in mammalian cells. Expression of the sequences encoding the antisense RNAs can be by any promoter known in the art to act in mammalian, preferably human, cells. Such promoters can be inducible or constitutive. Such promoters include, but are not limited to, the SV40 early promoter region (Bernoist and Chambon, 1981, Nature 290:304-310), the promoter contained in the 3' long terminal repeat of Rous sarcoma virus (Yamamoto et al., 1980, Cell 22:787-797), the herpes thymidine kinase promoter (Wagner et al., 1981, Proc. Natl. Acad. Sci. U.S.A. 78:1441-1445), the regulatory sequences of the metallothionein gene (Brinster et al., 1982, Nature 296:39-42), etc.

The antisense nucleic acids of the invention comprise a sequence complementary to at least a portion of an RNA transcript of a component protein gene, preferably a human gene. However, absolute complementarity, although preferred, is not required. A sequence "complementary to at least a portion of an RNA," as referred to herein, means a sequence having sufficient complementarity to be able to hybridize with the RNA, forming a stable duplex; in the case of double-stranded antisense nucleic acids, a single strand of the duplex DNA may thus be tested, or triplex formation may be assayed. The ability to hybridize will depend on both the degree of complementarity and the length of the antisense nucleic acid. Generally, the longer the hybridizing nucleic acid, the more base mismatches with a component protein RNA it may contain and still form a stable duplex (or triplex, as the case may be). One skilled in the art can ascertain a tolerable degree of mismatch by use of standard procedures to determine the melting point of the hybridized complex.

The component protein antisense nucleic acids can be used to treat (or prevent) disorders of a cell type that expresses, or preferably overexpresses, a protein complex.

Cell types that express or overexpress component protein RNA can be identified by various methods known in the art. Such methods include, but are not limited to, hybridization with component protein-specific nucleic acids (*e.g.*, by Northern blot hybridization, dot blot hybridization, or *in situ* hybridization), or by observing the ability of RNA from the cell type to be translated *in vitro* into the component protein by immunohistochemistry, Western blot analysis, ELISA, etc. In a preferred aspect, primary tissue from a patient can be assayed for protein expression prior to treatment, *e.g.*, by immunocytochemistry, *in situ* hybridization, or any number of methods to detect protein or mRNA expression.



Pharmaceutical compositions of the invention (see section 4.7), comprising an effective amount of a protein component antisense nucleic acid in a pharmaceutically acceptable carrier can be administered to a patient having a disease or disorder that is of a type that expresses or overexpresses a protein complex of the present invention.

5       The amount of antisense nucleic acid that will be effective in the treatment of a particular disorder or condition will depend on the nature of the disorder or condition, and can be determined by standard clinical techniques. Where possible, it is desirable to determine the antisense cytotoxicity in vitro, and then in useful animal model systems, prior to testing and use in humans.

10       In a specific embodiment, pharmaceutical compositions comprising antisense nucleic acids are administered via liposomes, microparticles, or microcapsules. In various embodiments of the invention, it may be useful to use such compositions to achieve sustained release of the antisense nucleic acids. In a specific embodiment, it may be desirable to utilize liposomes targeted via antibodies to specific identifiable central nervous system cell types (Leonetti et al.,  
15   1990, Proc. Natl. Acad. Sci. U.S.A. 87:2448-2451; Renneisen et al., 1990, J. Biol. Chem. 265:16337-16342).

#### 4.8.2 RNA Interference

In certain embodiments, an RNA interference (RNAi) molecule is used to decrease the  
20   expression of a component of a complex of the invention. RNA interference (RNAi) is the ability of double-stranded RNA (dsRNA) to suppress the expression of a gene corresponding to its own sequence (see, e.g., Cogoni and Macino, 2000, *Genes Dev* 10: 638-643, Guru, 2000, *Nature* 404, 804-808, Hammond et al., 2001, *Nature Rev Gen* 2: 110-119, Shi, 2003, *Trends Genet.* 19:9-12, US Patent 6,506,559, each incorporated by reference in their entireties herein).  
25   RNAi is also called post-transcriptional gene silencing or PTGS. Without being bound by theory, since the only RNA molecules normally found in the cytoplasm of a cell are molecules of single-stranded mRNA, the cell has enzymes that recognize and cut dsRNA into fragments containing 21-25 base pairs (approximately two turns of a double helix). The antisense strand of the fragment separates enough from the sense strand so that it hybridizes with the  
30   complementary sense sequence on a molecule of endogenous cellular mRNA. This hybridization triggers cutting of the mRNA in the double-stranded region, thus destroying its ability to be translated into a polypeptide. Introducing dsRNA corresponding to a particular

gene thus knocks out the cell's own expression of that gene in particular tissues and/or at a chosen time.

The current models of the RNAi mechanism includes both initiation and effector steps (Hutvagner and Zamore, 2002, *Curr Opin Genetics & Development* 12:225-32; Hammond et al., 2001, *Nature Rev Gen* 2: 110-9, each incorporated by reference in their entireties herein). In the initiation step, input dsRNA is digested into 21-23 nucleotide small interfering RNAs (siRNAs), which have also been called "guide RNAs" (Sharp, 2001, *Genes Dev* 15: 485-490). Evidence indicates that siRNAs are produced when the enzyme Dicer, a member of the RNase III family of dsRNA-specific ribonucleases, processively cleaves dsRNA (introduced directly or via a transgene or virus) in an ATP-dependent, processive manner. Successive cleavage events degrade the RNA to 19-21 base pair duplexes (siRNAs), each with 2-nucleotide 3' overhangs (Bernstein et al., 2001, *Nature* 409:363-366; Hutvagner and Zamore, 2002, *Curr Opin Genetics & Development* 12:225-232). In the effector step, the siRNA duplexes bind to a nuclease complex to form what is known as the RNA-induced silencing complex, or RISC. An ATP-dependent unwinding of the siRNA duplex is required for activation of the RISC. The active RISC then targets the homologous transcript by base pairing interactions and cleaves the mRNA ~12 nucleotides from the 3' terminus of the siRNA. Although the mechanism of cleavage is at this date unclear, research indicates that each RISC contains a single siRNA and an RNase that appears to be distinct from Dicer (Hutvagner and Zamore, 2002, *Curr Opin Genetics & Development* 12:225-232). Because of the remarkable potency of RNAi in some organisms, an amplification step within the RNAi pathway has also been proposed. Amplification could occur by copying of the input dsRNAs, which would generate more siRNAs, or by replication of the siRNAs themselves. Alternatively or in addition, amplification could be effected by multiple turnover events of the RISC.

Elbashir and colleagues (Elbashir et al., 2001, *Nature* 411:494-498; Elbashir et al., 2001, *EMBO* 20:6877-6888) have suggested a procedure for designing siRNAs for inducing RNAi in mammalian cells. Briefly, find a 21 nucleotide sequence in the mRNA of interest that begins with an adenine-adenine (AA) dinucleotide as a potential siRNA target site. This strategy for choosing siRNA target sites is based on the observation that siRNAs with 3' overhanging UU dinucleotides are the most effective. This is also compatible with using RNA pol III to transcribe hairpin siRNAs because RNA pol III terminates transcription at 4-6 nucleotide poly(T) tracts creating RNA molecules with a short poly(U) tail. Although siRNAs with other 3' terminal dinucleotide overhangs have been shown to effectively induce RNAi, siRNAs with

guanine residues in the overhang are not recommended because of the potential for the siRNA to be cleaved by RNase at single-stranded guanine residues. In addition to beginning with an AA dinucleotide, the siRNA target site should have a guanosine and cytidine residue percentage within the range of 30-70%. The chosen siRNA target sequence should then be subjected to a  
5 BLAST search against the EST database to ensure that only the desired gene is targeted. Various products are commercially available to aid in the preparation and use of siRNA (*e.g.*, Ambion, Inc., Austin, Texas).

Double-stranded (ds) RNA can be used to interfere with gene expression in mammals (Brummelkamp et al., *Science* 296:550-3, Krichevsky and Kosik, 2002, *PNAS* 99:11926-9,  
10 Paddison et al., 2002, *PNAS* 99:1443-8, Wianny & Zernicka-Goetz, 2000, *Nature Cell Biology* 2:70-75, European Patent 1144623, International Patent Publication Nos. WO 02/055693, WO 02/44321, WO 03/006,477; each incorporated by reference in their entireties herein).

#### **4.8.3 Other Anti-Cancer and Wound Healing Therapies**

15 The present invention provides methods of preventing, treating, managing or ameliorating cancer or one or more symptoms thereof, said methods comprising administering to a subject in need thereof one or more compounds identified in accordance with the methods of the invention and one or more therapies (*e.g.*, prophylactic or therapeutic agents). Therapeutic or prophylactic agents include, but are not limited to, peptides, polypeptides, fusion proteins,  
20 nucleic acid molecules, small molecules, mimetic agents, synthetic drugs, inorganic molecules, and organic molecules.

Any therapy (*e.g.*, chemotherapies, radiation therapies, hormonal therapies, and/or biological therapies/immunotherapies) which is known to be useful, or which has been used or is currently being used for the prevention, treatment, management or amelioration of cancer or one  
25 or more symptoms thereof can be used in combination with a compound identified in accordance with the methods of the invention. Examples of such agents (*i.e.*, anti-cancer agents) include, but are not limited to, angiogenesis inhibitors, topoisomerase inhibitors and immunomodulatory agents (such as chemotherapeutic agents). Angiogenesis inhibitors (*i.e.*, anti-angiogenic agents) include, but are not limited to, angiostatin (plasminogen fragment);  
30 antiangiogenic antithrombin III; angiozyme; ABT-627; Bay 12-9566; Benefin; Bevacizumab; BMS-275291; cartilage-derived inhibitor (CDI); CAI; CD59 complement fragment; CEP-7055; Col 3; combretastatin A-4; endostatin (collagen XVIII fragment); fibronectin fragment; Gro-

beta; Halofuginone; Heparinases; Heparin hexasaccharide fragment; HMV833; human chorionic gonadotropin (hCG); IM-862; Interferon alpha/beta/gamma; Interferon inducible protein (IP-10); Interleukin-12; Kringle 5 (plasminogen fragment); Marimastat; Metalloproteinase inhibitors (TIMPs); 2-methoxyestradiol; MMI 270 (CGS 27023A); MoAb IMC-1C11; Neovastat; NM-3; 5 Panzem; PI-88; Placental ribonuclease inhibitor; plasminogen activator inhibitor; platelet factor-4 (PF4); Prinomastat; Prolactin 16kD fragment; Proliferin-related protein (PRP); PTK 787/ZK 222594; retinoids; solimastat; squalamine; SS 3304; SU 5416; SU6668; SU11248; tetrahydrocortisol-S; tetrathiomolybdate; thalidomide; thrombospondin-1 (TSP-1); TNP-470; transforming growth factor-beta; vasculostatin; vasostatin (calreticulin fragment); ZD6126; ZD 10 6474; farnesyl transferase inhibitors (FTI); and bisphosphonates. In a specific embodiment, anti-angiogenic agents do not include antibodies or fragments thereof that immunospecifically bind to integrin  $\alpha_v\beta_3$ .

Specific examples of anti-cancer agents which can be used in accordance with the methods of the invention include, but not limited to: acivicin; aclarubicin; acodazole 15 hydrochloride; acronine; adozelesin; aldesleukin; altretamine; ambomycin; ametantrone acetate; aminoglutethimide; amsacrine; anastrozole; anthramycin; asparaginase; asperlin; azacitidine; azetepa; azotomycin; batimastat; benzodepa; bicalutamide; bisantrene hydrochloride; bisnafide dimesylate; bizelesin; bleomycin sulfate; brequinar sodium; broprimine; busulfan; cactinomycin; calusterone; caracemide; carbetimer; carboplatin; carmustine; carubicin 20 hydrochloride; carzelesin; cedefingol; chlorambucil; cirolemycin; cisplatin; cladribine; crisnatol mesylate; cyclophosphamide; cytarabine; dacarbazine; dactinomycin; daunorubicin hydrochloride; decitabine; dexormaplatin; dezaguanine; dezaguanine mesylate; diaziquone; docetaxel; doxorubicin; doxorubicin hydrochloride; droloxifene; droloxifene citrate; dromostanolone propionate; duazomycin; edatrexate; eflornithine hydrochloride; elsamitrucin; 25 enloplatin; enpromate; epipropidine; epirubicin hydrochloride; erbulozole; esorubicin hydrochloride; estramustine; estramustine phosphate sodium; etanidazole; etoposide; etoposide phosphate; etoprine; fadrozole hydrochloride; fazarabine; fenretinide; floxuridine; fludarabine phosphate; fluorouracil; flurocitabine; fosquidone; fostriecin sodium; gemcitabine; gemcitabine hydrochloride; hydroxyurea; idarubicin hydrochloride; ifosfamide; ilmofofosine; interleukin II 30 (including recombinant interleukin II, or rIL2), interferon alpha-2a; interferon alpha-2b; interferon alpha-n1 ; interferon alpha-n3; interferon beta-I a; interferon gamma-I b; ioproplatin; irinotecan hydrochloride; lanreotide acetate; letrozole; leuprolide acetate; liarozole hydrochloride; lometrexol sodium; lomustine; losoxantrone hydrochloride; masoprocol;

maytansine; mechlorethamine hydrochloride; megestrol acetate; melengestrol acetate;  
 melphalan; menogaril; mercaptopurine; methotrexate; methotrexate sodium; metoprine;  
 meturedopa; mitindomide; mitocarcin; mitocromin; mitogillin; mitomalcin; mitomycin;  
 mitosper; mitotane; mitoxantrone hydrochloride; mycophenolic acid; nocodazole; nogalamycin;  
 5 ormaplatin; oxisuran; paclitaxel; pegaspargase; peliomycin; pentamustine; peplomycin sulfate;  
 perfosfamide; pipobroman; piposulfan; piroxantrone hydrochloride; plicamycin; plomestane;  
 porfimer sodium; porfiromycin; prednimustine; procarbazine hydrochloride; puromycin;  
 puromycin hydrochloride; pyrazofurin; riboprime; rogletimide; safingol; safingol hydrochloride;  
 semustine; simtrazene; sparfosate sodium; sparsomycin; spirogermanium hydrochloride;  
 10 spiromustine; spiroplatin; streptonigrin; streptozocin; sulofenur; talisomycin; tecogalan sodium;  
 tegafur; teloxantrone hydrochloride; temoporfin; teniposide; teroxirone; testolactone;  
 thiamiprine; thioguanine; thiotepa; tiazofurin; tirapazamine; toremifene citrate; trestolone  
 acetate; triciribine phosphate; trimetrexate; trimetrexate glucuronate; triptorelin; tubulozole  
 hydrochloride; uracil mustard; uredepa; vapreotide; verteporfin; vinblastine sulfate; vincristine  
 15 sulfate; vindesine; vindesine sulfate; vinepidine sulfate; vinglycinatate sulfate; vinleurosine  
 sulfate; vinorelbine tartrate; vinrosidine sulfate; vinzolidine sulfate; vorozole; zeniplatin;  
 zinostatin; zorubicin hydrochloride. Other anti-cancer drugs include, but are not limited to:  
 20 20-epi-1,25 dihydroxyvitamin D<sub>3</sub>; 5-ethynyluracil; abiraterone; aclarubicin; acylfulvene;  
 adecypenol; adozelesin; aldesleukin; ALL-TK antagonists; altretamine; ambamustine; amidox;  
 25 amifostine; aminolevulinic acid; amrubicin; amsacrine; anagrelide; anastrozole;  
 andrographolide; angiogenesis inhibitors; antagonist D; antagonist G; antarelix; anti-dorsalizing  
 morphogenetic protein-1; antiandrogen, prostatic carcinoma; antiestrogen; antineoplaston;  
 antisense oligonucleotides; aphidicolin glycinate; apoptosis gene modulators; apoptosis  
 regulators; apurinic acid; ara-CDP-DL-PTBA; arginine deaminase; asulacrine; atamestane;  
 30 atrimustine; axinastatin 1; axinastatin 2; axinastatin 3; azasetron; azatoxin; azatyrosine; baccatin  
 III derivatives; balanol; batimastat; BCR/ABL antagonists; benzochlorins; benzoylstauroporine;  
 beta lactam derivatives; beta-alethine; betaclamycin B; betulinic acid; bFGF inhibitor;  
 bicalutamide; bisantrene; bisaziridinylspermine; bisnafide; bistratene A; bizelesin; breflate;  
 bropirimine; budotitane; buthionine sulfoximine; calcipotriol; calphostin C; camptothecin  
 35 derivatives; canarypox IL-2; capecitabine; carboxamide-amino-triazole; carboxyamidotriazole;  
 CaRest M3; CARN 700; cartilage derived inhibitor; carzelesin; casein kinase inhibitors (ICOS);  
 castanospermine; cecropin B; cetorelix; chlorlins; chloroquinoxaline sulfonamide; cicaprost;  
 cis-porphyrin; cladribine; clomifene analogues; clotrimazole; collismycin A; collismycin B;

- combretastatin A4; combretastatin analogue; conagenin; crambescidin 816; crisnatol; cryptophycin 8; cryptophycin A derivatives; curacin A; cyclopentantraquinones; cycloplatam; cypemycin; cytarabine ocfosfate; cytolytic factor; cytostatin; dacliximab; decitabine; dehydrodidemnin B; deslorelin; dexamethasone; dexifosfamide; dexrazoxane; dexverapamil;
- 5 diaziquone; didemnin B; didox; diethylnorspermine; dihydro-5-azacytidine; dihydrotaxol, 9-; dioxamycin; diphenyl spiromustine; docetaxel; docosanol; dolasetron; doxifluridine; droloxifene; dronabinol; duocarmycin SA; ebselen; ecomustine; edelfosine; edrecolomab; eflornithine; elemene; emitefur; epirubicin; epristeride; estramustine analogue; estrogen agonists; estrogen antagonists; etanidazole; etoposide phosphate; exemestane; fadrozole;
- 10 fazarabine; fenretinide; filgrastim; finasteride; flavopiridol; flezelastine; fluasterone; fludarabine; fluorodaunorubicin hydrochloride; forfenimex; formestane; fostriecin; fotemustine; gadolinium texaphyrin; gallium nitrate; galocitabine; ganirelix; gelatinase inhibitors; gemcitabine; glutathione inhibitors; hepsulfam; heregulin; hexamethylene bisacetamide; hypericin; ibandronic acid; idarubicin; idoxifene; idramantone; ilmofofosine; ilomastat;
- 15 imidazoacridones; imiquimod; immunostimulant peptides; insulin-like growth factor-1 receptor inhibitor; interferon agonists; interferons; interleukins; iobenguane; iododoxorubicin; ipomeanol, 4-; iroplact; irsogladine; isobengazole; isohomohalicondrin B; itasetron; jasplakinolide; kahalalide F; lamellarin-N triacetate; lanreotide; leinamycin; lenograstim; lentinan sulfate; leptolstatin; letrozole; leukemia inhibiting factor; leukocyte alpha interferon;
- 20 leuprolide+estrogen+progesterone; leuprorelin; levamisole; liarozole; linear polyamine analogue; lipophilic disaccharide peptide; lipophilic platinum compounds; lissoclinamide 7; lobaplatin; lombricine; lometrexol; lonidamine; losoxantrone; lovastatin; loxoribine; lurtotecan; lutetium texaphyrin; lysofylline; lytic peptides; maitansine; mannostatin A; marimastat; masoprocil; maspin; matrilysin inhibitors; matrix metalloproteinase inhibitors; menogaril;
- 25 merbarone; meterelin; methioninase; metoclopramide; MIF inhibitor; mifepristone; miltefosine; mirimostim; mismatched double stranded RNA; mitoguazone; mitolactol; mitomycin analogues; mitonafide; mitotoxin fibroblast growth factor-saporin; mitoxantrone; mofarotene; molgramostim; monoclonal antibody, human chorionic gonadotrophin; monophosphoryl lipid A+myobacterium cell wall sk; mopidamol; multiple drug resistance gene inhibitor; multiple
- 30 tumor suppressor 1-based therapy; mustard anticancer agent; mycaperoxide B; mycobacterial cell wall extract; myriaporone; N-acetyldinaline; N-substituted benzamides; nafarelin; nagrestip; naloxone+pentazocine; napavin; naphterpin; nartograstim; nedaplatin; nemorubicin; neridronic acid; neutral endopeptidase; nilutamide; nisamycin; nitric oxide modulators; nitroxide

antioxidant; nitrullin; O6-benzylguanine; octreotide; okicenone; oligonucleotides; onapristone; ondansetron; ondansetron; oracin; oral cytokine inducer; ormaplatin; osaterone; oxaliplatin; oxaunomycin; paclitaxel; paclitaxel analogues; paclitaxel derivatives; palauamine; palmitoylrhizoxin; pamidronic acid; panaxytriol; panomifene; parabactin; pazelliptine; 5 pegaspargase; peldesine; pentosan polysulfate sodium; pentostatin; pentroazole; perflubron; perfosfamide; perillyl alcohol; phenazinomycin; phenylacetate; phosphatase inhibitors; picibanil; pilocarpine hydrochloride; pirarubicin; piritrexim; placetin A; placetin B; plasminogen activator inhibitor; platinum complex; platinum compounds; platinum-triamine complex; porfimer sodium; porfiromycin; prednisone; propyl bis-acridone; prostaglandin J2; proteasome 10 inhibitors; protein A-based immune modulator; protein kinase C inhibitor; protein kinase C inhibitors, microalgal; protein tyrosine phosphatase inhibitors; purine nucleoside phosphorylase inhibitors; purpurins; pyrazoloacridine; pyridoxylated hemoglobin polyoxyethylene conjugate; raf antagonists; raltitrexed; ramosetron; ras farnesyl protein transferase inhibitors; ras inhibitors; ras-GAP inhibitor; retelliptine demethylated; rhenium Re 186 etidronate; rhizoxin; ribozymes; 15 RII retinamide; rogletimide; rohitukine; romurtide; roquinimex; rubiginone B1; ruboxyl; safingol; saintopin; SarCNU; sarcophytol A; sargramostim; Sdi 1 mimetics; semustine; senescence derived inhibitor 1; sense oligonucleotides; signal transduction inhibitors; signal transduction modulators; single chain antigen binding protein; sizofiran; sobuzoxane; sodium borocaptate; sodium phenylacetate; solverol; somatomedin binding protein; sonermin; sparfosic 20 acid; spicamycin D; spiromustine; splenopentin; spongistatin 1; squalamine; stem cell inhibitor; stem-cell division inhibitors; stipiamide; stromelysin inhibitors; sulfinosine; superactive vasoactive intestinal peptide antagonist; suradista; suramin; swainsonine; synthetic glycosaminoglycans; tallimustine; 5-fluorouracil; leucovorin; tamoxifen methiodide; tauromustine; tazarotene; tecogalan sodium; tegafur; tellurapyrylium; telomerase inhibitors; 25 temoporfin; temozolomide; teniposide; tetrachlorodecaoxide; tetrazomine; thaliblastine; thiocoraline; thrombopoietin; thrombopoietin mimetic; thymalfasin; thymopoietin receptor agonist; thymotrinan; thyroid stimulating hormone; tin ethyl etiopurpurin; tirapazamine; titanocene bichloride; topsentin; toremifene; totipotent stem cell factor; translation inhibitors; tretinoin; triacetyluridine; triciribine; trimetrexate; triptorelin; tropisetron; turosteride; tyrosine 30 kinase inhibitors; tyrphostins; UBC inhibitors; ubenimex; urogenital sinus-derived growth inhibitory factor; urokinase receptor antagonists; vapreotide; variolin B; vector system, erythrocyte gene therapy; thalidomide; velaresol; veramine; verdins; verteporfin; vinorelbine; vinxaltine; vorozole; zanoterone; zeniplatin; zilascorb; and zinostatin stimalamer.

The invention also encompasses the administration of one or more compounds identified in accordance with the methods of the invention in combination with radiation therapy comprising the use of x-rays, gamma rays and other sources of radiation to destroy the cancer cells. In preferred embodiments, the radiation treatment is administered as external beam  
5 radiation or teletherapy wherein the radiation is directed from a remote source. In other preferred embodiments, the radiation treatment is administered as internal therapy or brachytherapy wherein a radioactive source is placed inside the body close to cancer cells or a tumor mass.

Cancer therapies and their dosages, routes of administration and recommended usage are  
10 known in the art and have been described in such literature as the *Physician's Desk Reference* (56<sup>th</sup> ed., 2002).

#### **4.9 Compositions and Methods of Administering Compounds**

Compounds identified using the methods of the invention or a pharmaceutically  
15 acceptable salt thereof, complexes of the invention, components of complexes of the invention or nucleic acids encoding components of a complex of the invention, antibodies or fragment thereof that immunospecifically bind to a complex of the invention or a component of a complex of the invention or antisense oligonucleotides that interfere with the expression of a component of a complex of the invention can be administered to a patient, preferably a mammal, more  
20 preferably a human, suffering from a proliferative disorder, a disorder characterized by, associated with or caused by abnormal RNA-nucleolytic activity or a condition associated with wound healing (*e.g.*, sores, lesions, ulcers and bedsores). In this section, compounds identified using the methods of the invention or a pharmaceutically acceptable salt thereof, complexes of the invention, components of complexes of the invention or nucleic acids encoding components  
25 of a complex of the invention, antibodies or fragment thereof that immunospecifically bind to a complex of the invention or a component of a complex of the invention or antisense oligonucleotides that interfere with the expression of a component of a complex of the invention are collectively referred to as compound to be used with the therapeutic and prophylactic methods of the invention. In a specific embodiment, a compound to be used with the therapeutic  
30 and prophylactic methods of the invention is administered to a patient, preferably a mammal, more preferably a human, as a preventative measure against a proliferative disorder, a disorder characterized by, associated with or caused by abnormal RNA-nucleolytic activity or a condition



associated with wound healing.

When administered to a patient, the compound to be used with the therapeutic and prophylactic methods of the invention is preferably administered as component of a composition that optionally comprises a pharmaceutically acceptable vehicle. The composition can be administered orally, or by any other convenient route, for example, by infusion or bolus injection, by absorption through epithelial or mucocutaneous linings (*e.g.*, oral mucosa, rectal, and intestinal mucosa, *etc.*) and may be administered together with another biologically active agent. Administration can be systemic or local. Various delivery systems are known, *e.g.*, encapsulation in liposomes, microparticles, microcapsules, capsules, *etc.*, and can be used to administer the compound and pharmaceutically acceptable salts thereof.

Methods of administration include but are not limited to intradermal, intramuscular, intraperitoneal, intravenous, subcutaneous, intranasal, epidural, oral, sublingual, intranasal, intracerebral, intravaginal, transdermal, rectally, by inhalation, or topically, particularly to the ears, nose, eyes, or skin. The mode of administration is left to the discretion of the practitioner. In most instances, administration will result in the release of the compound or a pharmaceutically acceptable salt thereof into the bloodstream.

In specific embodiments, it may be desirable to administer the compound to be used with the therapeutic and prophylactic methods of the invention locally. This may be achieved, for example, and not by way of limitation, by local infusion during surgery, topical application, *e.g.*, in conjunction with a wound dressing after surgery, by injection, by means of a catheter, by means of a suppository, or by means of an implant, said implant being of a porous, non-porous, or gelatinous material, including membranes, such as sialastic membranes, or fibers.

In certain embodiments, it may be desirable to introduce the compound to be used with the therapeutic and prophylactic methods of the invention into the central nervous system by any suitable route, including intraventricular, intrathecal and epidural injection. Intraventricular injection may be facilitated by an intraventricular catheter, for example, attached to a reservoir, such as an Ommaya reservoir.

Pulmonary administration can also be employed, *e.g.*, by use of an inhaler or nebulizer, and formulation with an aerosolizing agent, or via perfusion in a fluorocarbon or synthetic pulmonary surfactant. In certain embodiments, the compound to be used with the therapeutic and prophylactic methods of the invention can be formulated as a suppository, with traditional binders and vehicles such as triglycerides.

In another embodiment, the compound to be used with the therapeutic and prophylactic

methods of the invention can be delivered in a vesicle, in particular a liposome (see Langer, 1990, Science 249:1527-1533; Treat et al., in Liposomes in the Therapy of Infectious Disease and Cancer, Lopez-Berestein and Fidler (eds.), Liss, New York, pp. 353-365 (1989); Lopez-Berestein, *ibid.*, pp. 317-327; see generally *ibid.*).

5           In yet another embodiment, the compound to be used with the therapeutic and prophylactic methods of the invention can be delivered in a controlled release system (see, *e.g.*, Goodson, in Medical Applications of Controlled Release, *supra*, vol. 2, pp. 115-138 (1984)). Other controlled-release systems discussed in the review by Langer, 1990, Science 249:1527-1533 may be used. In one embodiment, a pump may be used (see Langer, *supra*;  
10   Sefton, 1987, CRC Crit. Ref. Biomed. Eng. 14:201; Buchwald et al., 1980, Surgery 88:507; Saudek et al., 1989, N. Engl. J. Med. 321:574). In another embodiment, polymeric materials can be used (see Medical Applications of Controlled Release, Langer and Wise (eds.), CRC Pres., Boca Raton, Florida (1974); Controlled Drug Bioavailability, Drug Product Design and Performance, Smolen and Ball (eds.), Wiley, New York (1984); Ranger and Peppas, 1983, J.  
15   Macromol. Sci. Rev. Macromol. Chem. 23:61; see also Levy et al., 1985, Science 228:190; During et al., 1989, Ann. Neurol. 25:351; Howard et al., 1989, J. Neurosurg. 71:105). In yet another embodiment, a controlled-release system can be placed in proximity of a target RNA of the compound or a pharmaceutically acceptable salt thereof, thus requiring only a fraction of the systemic dose.

20           Compositions comprising the compound to be used with the therapeutic and prophylactic methods of the invention ("compound compositions") can additionally comprise a suitable amount of a pharmaceutically acceptable vehicle so as to provide the form for proper administration to the patient.

          In a specific embodiment, the term "pharmaceutically acceptable" means approved by a  
25   regulatory agency of the Federal or a state government or listed in the U.S. Pharmacopeia or other generally recognized pharmacopeia for use in animals, mammals, and more particularly in humans. The term "vehicle" refers to a diluent, adjuvant, excipient, or carrier with which a compound of the invention is administered. Such pharmaceutical vehicles can be liquids, such as water and oils, including those of petroleum, animal, vegetable or synthetic origin, such as  
30   peanut oil, soybean oil, mineral oil, sesame oil and the like. The pharmaceutical vehicles can be saline, gum acacia, gelatin, starch paste, talc, keratin, colloidal silica, urea, and the like. In addition, auxiliary, stabilizing, thickening, lubricating and coloring agents may be used. When administered to a patient, the pharmaceutically acceptable vehicles are preferably sterile. Water

is a preferred vehicle when the compound of the invention is administered intravenously. Saline solutions and aqueous dextrose and glycerol solutions can also be employed as liquid vehicles, particularly for injectable solutions. Suitable pharmaceutical vehicles also include excipients such as starch, glucose, lactose, sucrose, gelatin, malt, rice, flour, chalk, silica gel, sodium stearate, glycerol monostearate, talc, sodium chloride, dried skim milk, glycerol, propylene, glycol, water, ethanol and the like. Compound compositions, if desired, can also contain minor amounts of wetting or emulsifying agents, or pH buffering agents.

Compound compositions can take the form of solutions, suspensions, emulsion, tablets, pills, pellets, capsules, capsules containing liquids, powders, sustained-release formulations, suppositories, emulsions, aerosols, sprays, suspensions, or any other form suitable for use. In one embodiment, the pharmaceutically acceptable vehicle is a capsule (see *e.g.*, U.S. Patent No. 5,698,155). Other examples of suitable pharmaceutical vehicles are described in Remington's Pharmaceutical Sciences, Alfonso R. Gennaro, ed., Mack Publishing Co. Easton, PA, 19th ed., 1995, pp. 1447 to 1676, incorporated herein by reference.

In a preferred embodiment, the compound to be used with the therapeutic and prophylactic methods of the invention is formulated in accordance with routine procedures as a pharmaceutical composition adapted for oral administration to human beings. Compositions for oral delivery may be in the form of tablets, lozenges, aqueous or oily suspensions, granules, powders, emulsions, capsules, syrups, or elixirs, for example. Orally administered compositions may contain one or more agents, for example, sweetening agents such as fructose, aspartame or saccharin; flavoring agents such as peppermint, oil of wintergreen, or cherry; coloring agents; and preserving agents, to provide a pharmaceutically palatable preparation. Moreover, where in tablet or pill form, the compositions can be coated to delay disintegration and absorption in the gastrointestinal tract thereby providing a sustained action over an extended period of time. Selectively permeable membranes surrounding an osmotically active driving compound are also suitable for orally administered compositions. In these later platforms, fluid from the environment surrounding the capsule is imbibed by the driving compound, which swells to displace the agent or agent composition through an aperture. These delivery platforms can provide an essentially zero order delivery profile as opposed to the spiked profiles of immediate release formulations. A time delay material such as glycerol monostearate or glycerol stearate may also be used. Oral compositions can include standard vehicles such as mannitol, lactose, starch, magnesium stearate, sodium saccharine, cellulose, magnesium carbonate, and the like. Such vehicles are preferably of pharmaceutical grade. Typically, compositions for intravenous

administration comprise sterile isotonic aqueous buffer. Where necessary, the compositions may also include a solubilizing agent.

In another embodiment, the compound to be used with the therapeutic and prophylactic methods of the invention can be formulated for intravenous administration. Compositions for intravenous administration may optionally include a local anesthetic such as lignocaine to lessen pain at the site of the injection. Generally, the ingredients are supplied either separately or mixed together in unit dosage form, for example, as a dry lyophilized powder or water-free concentrate in a hermetically sealed container such as an ampoule or sachette indicating the quantity of active agent. Where the compound to be used with the therapeutic and prophylactic methods of the invention is to be administered by infusion, it can be dispensed, for example, with an infusion bottle containing sterile pharmaceutical grade water or saline. Where the compound to be used with the therapeutic and prophylactic methods of the invention is administered by injection, an ampoule of sterile water for injection or saline can be provided so that the ingredients may be mixed prior to administration.

The amount of a compound to be used with the therapeutic and prophylactic methods of the invention that will be effective in the treatment of a particular disease will depend on the nature of the disease, and can be determined by standard clinical techniques. In addition, *in vitro* or *in vivo* assays may optionally be employed to help identify optimal dosage ranges. The precise dose to be employed will also depend on the route of administration, and the seriousness of the disease, and should be decided according to the judgment of the practitioner and each patient's circumstances. However, suitable dosage ranges for oral administration are generally about 0.001 milligram to about 500 milligrams of a compound or a pharmaceutically acceptable salt thereof per kilogram body weight per day. In specific preferred embodiments of the invention, the oral dose is about 0.01 milligram to about 100 milligrams per kilogram body weight per day, more preferably about 0.1 milligram to about 75 milligrams per kilogram body weight per day, more preferably about 0.5 milligram to 5 milligrams per kilogram body weight per day. The dosage amounts described herein refer to total amounts administered; that is, if more than one compound is administered, or if a compound is administered with a therapeutic agent, then the preferred dosages correspond to the total amount administered. Oral compositions preferably contain about 10% to about 95% active ingredient by weight.

Suitable dosage ranges for intravenous (i.v.) administration are about 0.01 milligram to about 100 milligrams per kilogram body weight per day, about 0.1 milligram to about 35 milligrams per kilogram body weight per day, and about 1 milligram to about 10 milligrams per

kilogram body weight per day. Suitable dosage ranges for intranasal administration are generally about 0.01 pg/kg body weight per day to about 1 mg/kg body weight per day. Suppositories generally contain about 0.01 milligram to about 50 milligrams of a compound of the invention per kilogram body weight per day and comprise active ingredient in the range of about 0.5% to about 10% by weight.

Recommended dosages for intradermal, intramuscular, intraperitoneal, subcutaneous, epidural, sublingual, intracerebral, intravaginal, transdermal administration or administration by inhalation are in the range of about 0.001 milligram to about 200 milligrams per kilogram of body weight per day. Suitable doses for topical administration are in the range of about 0.001 milligram to about 1 milligram, depending on the area of administration. Effective doses may be extrapolated from dose-response curves derived from *in vitro* or animal model test systems. Such animal models and systems are well known in the art.

The compound and pharmaceutically acceptable salts thereof are preferably assayed *in vitro* and *in vivo*, for the desired therapeutic or prophylactic activity, prior to use in humans. For example, *in vitro* assays can be used to determine whether it is preferable to administer the compound, a pharmaceutically acceptable salt thereof, and/or another therapeutic agent. Animal model systems can be used to demonstrate safety and efficacy.

An exemplary doses of proteins, polypeptides, peptides, fusion proteins and complexes encompassed by the invention is 0.0001 mg/kg to 100 mg/kg of the patient's body weight. Preferably, the dosage administered to a patient is between 0.0001 mg/kg and 20 mg/kg, 0.0001 mg/kg and 10 mg/kg, 0.0001 mg/kg and 5 mg/kg, 0.0001 and 2 mg/kg, 0.0001 and 1 mg/kg, 0.0001 mg/kg and 0.75 mg/kg, 0.0001 mg/kg and 0.5 mg/kg, 0.0001 mg/kg and 0.25 mg/kg, 0.0001 and 0.15 mg/kg, 0.0001 and 0.10 mg/kg, 0.001 and 0.5 mg/kg, 0.01 and 0.25 mg/kg, 0.01 and 0.10 mg/kg or 0.1 and 10 mg/kg of the patient's body weight.

#### **4.10 Diagnostic Methods of the Invention**

In certain embodiments, the invention provides methods for diagnosing the presence of a proliferative disorder in a subject. In certain embodiments, a diagnostic method of the invention comprises determining the amount of a complex of the invention in a subject, wherein a decreased level of a complex of the invention in the subject indicates the presence of a proliferative disorder or an increased risk of developing a proliferative disorder. In other embodiments, a diagnostic method of the invention comprises determining the amount of a

component of a complex (or a nucleic acid encoding the component) of the invention in a subject, wherein a decreased level of the component in the subject indicates the presence of a proliferative disorder or an increased risk of developing a proliferative disorder. In yet other embodiments, a diagnostic method of the invention comprises determining the amount of a component of a complex of the invention in the nuclei of cells in a subject, wherein a increased level of the component in the subject indicates the presence of a proliferative disorder or an increased risk of developing a proliferative disorder.

A component of a complex, a nucleic acid encoding a component of a complex of the invention can be detected and quantified by any method known to the skilled artisan.

Exemplary methods include, but are not limited to, Western blot analysis, radioimmunoassays, ELISA (enzyme linked immunosorbent assay), "sandwich" immunoassays, immunoprecipitation assays, precipitin reactions, gel diffusion precipitin reactions, immunodiffusion assays, agglutination assays, complement-fixation assays, immunoradiometric assays, fluorescent immunoassays, protein A immunoassays for proteins and PCR (particularly RT-PCR) or Northern blot analysis for nucleic acids.

The invention also provides methods for detecting, diagnosing or monitoring a proliferative disorder or a disorder associated with, characterized by or caused by abnormal pre-tRNA processing and/or 3' end pre-mRNA processing utilizing an antibody that immunospecifically binds to a complex of the invention or a component thereof, or a compound identified in accordance with the methods of the invention that specifically binds to a complex of the invention or a component thereof. In a specific embodiment, the invention provides a method for detecting, diagnosing or monitoring a proliferative disorder or a disorder associated with, characterized by or caused by increased pre-tRNA processing and/or 3' end pre-mRNA processing, said method comprising: (a) measuring the level of a complex of the invention or a component thereof in cells or a tissue sample of a subject (*e.g.*, a subject with such a disorder or suspected of having such disorder) using one or more antibodies or fragments thereof that immunospecifically bind to the complex or a component thereof, or a compound identified in accordance with the methods of the invention that specifically binds to the complex or a component thereof; and (b) comparing the level of the complex or a component thereof with a control level, *e.g.*, levels in normal, noncancerous cells or tissue samples, wherein an increase in the measured complex or component level in measured in (a) relative to the control level of the complex or component is indicates that the subject has a proliferative disorder or a disorder associated with, characterized by or caused by abnormal pre-tRNA processing and/or 3' end pre-

mRNA processing.

The invention provides methods for detecting, diagnosing or monitoring a proliferative disorder or a disorder associated with, characterized by or caused by abnormal pre-tRNA processing and/or 3' end pre-mRNA processing by comparing the RNA-nucleolytic activity of a complex purified from cells or a tissue sample from a subject with such a disorder or suspected of having such disorder to the RNA-nucleolytic activity of a control, *e.g.*, a complex purified from normal, non-cancerous cells or a tissue sample, using an assay well-known to one of skill in the art or described herein. In a specific embodiment, the invention provides a method for detecting, diagnosing or monitoring a proliferative disorder or a disorder associated with, characterized by or caused by increased RNA-nucleolytic activity (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention), the method comprising (a) measuring the RNA-nucleolytic activity of a complex of the invention purified from cells or a tissue sample from a subject with such a disorder or suspected of having such disorder to the RNA-nucleolytic activity of a control, *e.g.*, a complex purified from normal, non-cancerous, cells or a tissue sample using an assay well-known to one of skill in the art or described herein; and (b) comparing the RNA-nucleolytic activity of the complex measured in (a) with the RNA-nucleolytic activity of a control, *e.g.*, a complex of the invention purified from normal, non-cancerous, cells or a tissue sample, wherein an increase in the RNA-nucleolytic activity in measured in (a) relative to the control indicates that the subject has a proliferative disorder or a disorder associated with, characterized by or caused by increased pre-tRNA processing and/or 3' end pre-mRNA processing. In another embodiment, the invention provides a method for detecting, diagnosing or monitoring a disorder associated with, characterized by or caused by decreased RNA-nucleolytic activity (*e.g.*, the pre-tRNA splicing endonuclease activity, the 3' end pre-mRNA endonuclease activity, the pre-tRNA cleavage activity of a complex of the invention, and/or the pre-ribosomal RNA cleavage activity of a complex of the invention), the method comprising measuring the RNA-nucleolytic activity of a complex of the invention purified from cells or a tissue sample from a subject with such a disorder or suspected of having such disorder to the RNA-nucleolytic activity of a control, *e.g.*, a complex of the invention purified from normal, non-cancerous, cells or a tissue sample using an assay well-known to one of skill in the art or described herein; (b) comparing the RNA-nucleolytic activity of the complex measured in (a) with the RNA-nucleolytic activity of a control, *e.g.*, a complex purified from normal, non-cancerous, cells or a tissue sample, wherein a

decrease in the RNA-nucleolytic activity in measured in (a) relative to the control indicates that the subject has a disorder associated with, characterized by or caused by decreased pre-tRNA processing and/or 3' end pre-mRNA processing.

The invention provides methods for detecting, diagnosing or monitoring a proliferative disorder or a disorder associated with, characterized by or caused by abnormal pre-tRNA processing and/or 3' end pre-mRNA processing by comparing the structure of a complex of the invention purified from cells or a tissue sample from a subject (*e.g.*, a subject with such a disorder or suspected of having such a disorder) to the structure of a control, *e.g.*, a complex of the invention purified from normal, non-cancerous cells or a tissue sample, using an assay well-known to one of skill in the art (*e.g.*, circular circular dichroism and nuclear magnetic resonance).

## 5. EXAMPLE

The Example below describes a human endonuclease complex and demonstrates a molecular connection between tRNA splicing and pre-mRNA 3'-end formation.

### Introduction

Maturation of cellular RNAs is critical for regulation of normal cell growth and division. Mature eukaryotic RNAs are generated from large precursors via a series of processing steps. For example, nascent pre-mRNAs undergo splicing, capping, and generation of 3' ends by endonucleolytic cleavage and polyadenylation. The maturation of precursor transfer RNA (pre-tRNA) requires several steps that include: 1) removal of both the 5' leader by RNase P (Xiao et al., 2002; Frank and Pace, 1998) and the 3' trailer by ELAC2 (Takaku et al., 2003); 2) addition of the CCA trinucleotide to the 3' end; 3) numerous nucleotide modifications (reviewed in Hopper and Phizicky, 2003). In addition, several tRNAs contain introns that must be removed to produce a mature tRNA molecule.

Intron-containing pre-tRNAs are found in a variety of organisms from all three domains of life. In lower eukaryotes, approximately 25% of all tRNA genes contain introns (Trotta et al., 1997), whereas in humans only 6% of tRNA genes contain introns (Lowe and Eddy, 1997). All eukaryotic tRNA introns are 14-60 nucleotides in length and interrupt the anticodon loop one nucleotide 3' to the anticodon (Ogden et al., 1984). Among all yeast pre-tRNAs, there is no sequence conservation at the splice junctions, but the 3' splice site is invariably located in a bulged loop (Baldi et al., 1992).



The removal of introns from pre-tRNA is an enzymatic reaction that requires the activity of several different proteins (reviewed in Abelson et al., 1998). These enzymes have been most intensively investigated in Archaea and yeast. The first step is carried out by an evolutionarily conserved tRNA splicing endonuclease that recognizes and cleaves precursor tRNA at the 5' and 3' splice sites (Trotta et al., 1997). In yeast, the 5' and 3' exons are ligated by a tRNA ligase through a series of enzymatic reactions that lead to joining of the two exons with a 2' phosphate at the splice junction (Westaway et al., 1988; Phizicky et al., 1986). This unusual tRNA intermediate is then processed by a 2' phosphotransferase yielding a mature tRNA (Culver et al., 1997).

Yeast tRNA splicing endonuclease is a heteromeric complex of four subunits encoded by the *SEN2*, *SEN34*, *SEN54* and *SEN15* genes (Rauhut et al., 1990; Trotta et al., 1997). All four subunits are present at low levels and are essential for cell viability (Trotta et al., 1997). The structure and function of the factors of the yeast tRNA endonuclease complex has been suggested from a number of experimental results. First, strong sequence conservation of the yeast Sen2p and Sen34p to the homotetrameric archaeal enzyme suggested that these two subunits each contained a distinct active site for cleavage at the 5' and 3' sites. Consistent with this view, a mutation in Sen2p resulted in a defect in cleavage of the 5' splice site (Ho et al., 1990), whereas a mutation in a conserved histidine residue in Sen34p resulted in a defect in cleavage of the 3' splice site (Trotta et al., 1997). Second, two-hybrid analysis demonstrated strong interaction between Sen2p and Sen54p and between Sen34p and Sen15p (Trotta et al., 1997). Structural studies with the homotetrameric archaeal tRNA endonuclease suggested that the strong interaction between Sen2p-Sen54p and Sen34p-Sen15p are mediated by a conserved carboxyl-terminal beta-sheet interaction (Lykke-Andersen and Garrett, 1997; Li et al., 1998). Finally, sequence alignment of heterologous subunits Sen54p and Sen15p to the archaeal endonuclease revealed a conserved structural element near the carboxyl-terminus required for dimerization of the two yeast heterodimers, Sen54p-Sen2p and Sen15p-Sen34p (Lykke-Andersen and Garrett, 1997; Li et al., 1998). Together, these results led to a model for the configuration of the yeast tRNA splicing endonuclease (Li et al., 1998; Abelson et al., 1998).

Preliminary studies suggest a common mechanism for tRNA splicing throughout evolution. For example, extracts derived from human cell lines were reported to carry out accurate tRNA splicing under conditions in which the yeast tRNA splicing endonuclease is active (Laski et al., 1983; Standring et al., 1981). Furthermore, partially purified tRNA splicing endonuclease from *Xenopus laevis* germinal vesicles was shown to recognize and accurately cleave yeast pre-tRNA, forming two half-molecules and an intron (Gandini-Attardi et al., 1990;

Baldi et al., 1986; Otsuka et al., 1981). Additionally, *Xenopus* and yeast enzymes appear to fix the sites of cleavage by recognition of local structures at the intron-exon boundaries (Baldi et al., 1992; Fabbri et al., 1998).

Although there is evidence that the mechanism of tRNA splicing is well conserved  
 5 between yeast, archaea and higher eukaryotes, the enzymes responsible for the maturation of pre-tRNA in humans are unknown. The present example describes present the isolation and characterization of human tRNA splicing endonuclease. In addition, the present example describes the identification a distinct endonuclease complex resulting from alternative splicing of the SEN2 subunit. This complex differs from tRNA endonuclease complex by protein  
 10 composition and the ability to process pre-tRNA. Furthermore, the endonuclease complex associates with factors required for cleavage/polyadenylation of mRNAs, suggesting a previously undiscovered biochemical link between pre-tRNA splicing and formation of the 3' end of messenger RNAs.

## 15            **5.1   Subunits of the Human Endonuclease Complex**

### **5.1.1   Materials and Methods**

#### **5.1.1.1   Generation of stable cell lines that express HIS-FLAG-tagged endonuclease complex subunits**

Endonuclease complex subunits include the proteins Sen2 (80746), Sen34 (79042),  
 20 Sen54 (283989), Sen15 (116461), and Clp1 (10978). The open reading frame of Sen2 was generated by PCR amplification using specific primers (Forward: cgggatcccgagcagaagcagtttccatgccccaaagagg (SEQ ID NO:21); Reverse: gctctagattaaagatcgcttggcactcctctctcg (SEQ ID NO:22)) and was cloned into the HIS-FLAG-pcDNA3.1/Hygro vector containing a gene that provides resistance to hygromycin. 293T cells  
 25 that contain other necessary components of the endonuclease complex were transfected with HIS-FLAG-pcDNA3.1/Hygro plasmid encoding His-Flag-Sen2 (His-Flag-Sen2 vector), and stable clones were selected by resistance to hygromycin to generate cell lines expressing His-Flag-Sen2. 293 cell lines expressing His-Flag-Sen34 and His-Flag-Sen15 were generated similarly. The open reading frame of Sen34 was generated by PCR amplification using primers  
 30 specific for Sen34 (Forward: cgggatcccctggtggtggagggtggcgaacggccgctcc (SEQ ID NO:23); Reverse: gctctagatgcaggctggccattgcaggaggtgtag (SEQ ID NO:24)) and was cloned into the HIS-FLAG-pcDNA3.1/Hygro vector to create HIS-FLAG-Sen34 vector. 293T cells were transfected with

the HIS-FLAG-Sen34 vector, and stable clones were selected by resistance to hygromycin to generate cell lines expressing His-Flag-Sen34. The open reading frame of Sen15 was generated by PCR amplification using primers specific for Sen15 (Forward:

cgggatcccaggagcgcgggcgattccgagccga (SEQ ID NO:25); Reverse:

- 5 cgcgctagctcatcttctaagagaaatattctgagggctctggcag (SEQ ID NO:26)) and was cloned into the HIS-FLAG-pcDNA3.1/Hygro vector to create HIS-FLAG-Sen15 vector. 293T cells were transfected with the HIS-FLAG-Sen15 vector, and stable clones were selected by resistance to hygromycin to generate cell lines expressing His-Flag-Sen15. The open reading frame of Sen54 was generated by PCR amplification using primers specific for Sen54 (Forward:
- 10 atcgggatcccagcccagcccagcccagccc (SEQ ID NO:27); Reverse: gctctagatcagtgccccacatctctggggc (SEQ ID NO:28)) and was cloned into the HIS-FLAG-pcDNA3.1/Hygro vector to create HIS-FLAG-Sen54 vector. 293T cells are transfected with the HIS-FLAG-Sen54 vector, and stable clones are selected by resistance to hygromycin to generate cell lines expressing His-Flag-Sen54. The open reading frame of Clp1 was generated by PCR amplification using primers specific for Clp1
- 15 (Forward: cgggatcccgagaagaggctaagatgatgacaagaag (SEQ ID NO:29); Reverse: gctctagactacttcagatccatgaaccggatatcc (SEQ ID NO:30)) and was cloned into the HIS-FLAG-pcDNA3.1/Hygro vector to create HIS-FLAG-Clp1 vector. 293T cells were transfected with the HIS-FLAG-Clp1 vector, and stable clones were selected by resistance to hygromycin to generate cell lines expressing His-Flag-Clp1.

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#### **5.1.1.2 Purification of the endonuclease complex from a total cell extract containing His-Flag-tagged proteins.**

- Total cell extracts were prepared by resuspending cell pellets in buffer B (250 mM NaCl; 30 mM Tris-HCl, pH 7.0; 1 mM EDTA; 5 % glycerol; 0.1% Triton X-100; Protease inhibitors
- 25 (Roche, Complete Protease Inhibitor Cocktail Tablets)). Cells were sonicated 3 times for 10 seconds, followed by centrifugation at 15,000 g for 15 minutes. Supernatants were passed through a 0.2 µm filter and added to anti-Flag beads (Sigma) pre-washed with buffer B. Extracts were incubated with anti-Flag beads for 2 hours at 4°C. Supernatants were discarded and beads were washed 3 times for 10 minutes at 4°C with ten bed volumes of buffer W (400
- 30 mM NaCl; 30 mM Tris-HCl, pH 7.0; 1 mM EDTA; 5% glycerol; 0.04% Triton X-100). Following two washes with ten bed volumes of buffer N (200 mM NaCl; 40 mM Tris-HCl, pH 7.0; 2 mM MgCl<sub>2</sub>; 5% glycerol; 0.05% triton X-100), bound proteins were eluted with three bed volumes of buffer N containing 0.25 mg/ml 3xFLAG peptide (Sigma) for 1 h at 4°C. Following

addition of NaCl (final concentration of 480 mM), eluted proteins were added to Ni-beads pre-washed with buffer NBW (500 mM NaCl; 40 mM Tris-HCl, pH 7.0; 2 mM MgCl<sub>2</sub>; 5% glycerol; 0.05% triton X-100) and incubated for 1 hour at 4°C. Supernatants were discarded and Ni-beads were washed three times with ten bed volumes of buffer NB (200 mM NaCl; 40 mM Tris-HCl, pH 7.0; 2 mM MgCl<sub>2</sub>; 5% glycerol; 0.05% triton X-100, 15 mM imidazole) for 10 minutes at 4°C. Bound proteins were eluted with three bed volumes of buffer NE (200 mM NaCl; 40 mM Tris-HCl, pH 7.0; 2 mM MgCl<sub>2</sub>; 5% glycerol; 0.05% triton X-100, 250 mM imidazole), and equal amount of 80% glycerol was added to eluted proteins. The proteins were stored at -20°C.

## 5.1.2 Results

### 5.1.2.1 Identification of subunits of the pre-tRNA human endonuclease complex.

Yeast Sen2, Sen54 and Sen34 were blasted against the human protein database. Alignments of the amino acid sequences of the respective proteins are shown in Fig.5, Fig.6, and Fig.7. To identify new components of the human tRNA splicing complex, stable cell lines expressing human His-Flag-Sen2 and His-Flag-Sen34 fusion proteins were generated as described above. Polypeptides that co-purify with His-Flag-Sen2 and His-Flag-Sen34 were isolated and identified by gel electrophoresis. Extracts from untransfected 293T cells were used as a negative control. As shown in Fig. 9, two new proteins were found to be co-purified with His-Flag-Sen2 and His-Flag-Sen34. These were Sen15 and Clp1. To confirm that Sen15 and Clp1 are the subunits of the endonuclease complex, stable cell lines expressing His-Flag-Sen15 and His-Flag-Clp1 proteins were generated as described above. Proteins co-purified with His-Flag-Sen15 and His-Flag-Clp1 were analyzed by SDS-PAGE followed by a silver staining. As shown in Fig. 9, components of the endonuclease complex, Sen2, Sen34, and Sen54 were co-purified with His-Flag-Sen15 and His-Flag-Clp1, demonstrating that Cpl1 and Sen15 are the subunits of the human endonuclease complex.

### 5.1.2.2 Proteins Co-purifying with Sen2, Sen34, Sen15 and Clp1 have pre-tRNA Splicing Endonuclease Activity

The endonuclease complex was purified from stable cell lines expressing His-Flag-Sen2 or His-Flag-Sen34 as described *supra*. Yeast endonuclease was used as a positive control for endonuclease activity (Trotta et al., 1997, Cell 89, 849-858). Cell extract fractions that co-purify

with His-Flag-Sen2 and His-Flag-Sen34 show endonuclease activity, as demonstrated by cleavage of labeled phenylalanine pre-tRNA at intron/exon borders (Fig. 10). The generation of pre-tRNA substrate was performed according to Trotta et al., 1997, Cell 89, 849-859. Similarly, fractions that co-purify with His-Flag-Sen15 and His-Flag-Clp1 also show endonuclease activity and pre-tRNA cleavage (Fig. 10), demonstrating that Sen2, Sen34, Sen54, Sen15 and Clp1 are components of the pre-tRNA splicing endonuclease complex.

#### 5.1.2.3 Human tRNA Splicing Endonuclease Subunits are Localized in the Nucleus

The open reading frame of Sen2 was generated by PCR amplification using specific primers (cgggatccgcagaagcagtttccatgccccaaagagg (SEQ ID NO:21), agaatagcggccgcttaagatcgtcttggtcactcc (SEQ ID NO:31)) and was cloned into the myc-pcDNA3 vector to create myc-Sen2 vector. The open reading frame of Sen34 was generated by PCR amplification using primers specific for Sen34 (cgggatccctggtggtggaggtggcgaacggccgcctcc (SEQ ID NO:23), gctctagatgcaggctggcccattgcaggagggtgtag (SEQ ID NO:24)) and was cloned into the GFP-pcDNA3 vector to create GFP-Sen34 vector. To examine the cellular distribution of tRNA splicing endonuclease components, myc-Sen2 and GFP-Sen34 vectors were transiently transfected into Hela cells and immunofluorescence was performed as described previously (Choi and Dreyfuss, 1984, J. Cell. Biol. 99, 1997-2004). It was found that both myc-Sen2p and GFP-Sen34p localize to the nucleus (Fig. 11). This nuclear localization demonstrates that pre-tRNA splicing takes place in the nucleus.

#### 5.1.2.4 Sen2 Splice Variant is expressed in different tissues and cell lines.

It was found that human Sen2 is spliced into two different variants (Fig. 12). The first splice form, Sen2WT, contains all 13 exons of the Sen2 gene. The second splice form contains an alternate splicing of Exon 7 to Exon 9, bypassing Exon 8, to form the novel splice variant Sen2ΔEx8. In order to determine the presence of alternatively spliced variant of Sen2 in different tissues, cDNA libraries obtained from different tissues (Clontech) are examined by PCR using the primers located outside of exon 8: (gagtacgtgctggtcgaggaagcg (SEQ ID NO:32), gagtccactttgggctccagcc (SEQ ID NO:33)). As shown in Fig. 13, all examined tissues contain both, Sen2WT and Sen2ΔEx8 variant. To further determine a profile of Sen2ΔEx8 expression over a range of human tissues and cancer cell lines, "BD MTE Human Multiple Tissue Expression Array" (BD, Clontech) was hybridized with an oligonucleotide specific for Exon 8

of Sen2 (gctctgggatgtttaagtatttac (SEQ ID NO:34)). Hybridization procedure was carried out according to the manufacture's instruction (BD, Clontech, user manual PT3307-1)

5                   **5.1.2.5    Fidelity and Accuracy of Pre-tRNA Cleavage Activity of Complexes Containing Sen2ΔEx8 is Compromised**

A purified complex from a stable cell line expressing His-Flag-Sen2ΔEx8 was obtained as described, *e.g.*, in section 5.1.1.2. Extracts from untransfected 293T cells were used as a negative control, whereas 293T cells stably expressing His-Flag-Sen2 or His-Flag-Sen34 were used as a positive control. Yeast endonuclease was used as additional positive control for  
10    endonuclease activity (Trotta *et al.*, 1997, Cell 89:849-858). The generation of pre-tRNA substrate was performed according to Trotta *et al.*, 1997, Cell 89:849-859. Cell extract fractions that co-purify with His-Flag-Sen2ΔEx8 show reduced endonuclease activity compared to fractions that co-purify with His-Flag-Sen2 or His-Flag-Sen34 (Fig. 15), demonstrating that the fidelity and accuracy of pre-tRNA cleavage activity complex containing Sen2ΔEx8 is  
15    compromised. Fractions co-purifying with His-Flag-Sen2ΔEx8 contain reduced levels of Sen34 and Sen15 proteins compared with levels of Sen34 and Sen15 proteins in fractions that co-purify with His-Flag-Sen2 or His-Flag-Sen34 (Fig. 14), demonstrating that His-Flag-Sen2ΔEx8 has decreased ability to bind Sen15 and Sen34.

20                   **5.1.2.6    The endonuclease complexes are associated with 3' end pre-mRNA processing machinery.**

Complexes from stable cell lines expressing His-Flag-Sen2, His-Flag-Sen2ΔEx8, His-Flag-Sen34, His-Flag-Clp1, His-Flag-Sen15 were purified as described above (see, *e.g.*, section 5.1.1.2). Proteins co-purified with His-Flag-Sen2, His-Flag-Sen2ΔEx8, His-Flag-Sen34,  
25    His-Flag-Clp1, His-Flag-Sen15 were analyzed by SDS-PAGE followed by a Western blotting with antibodies against components of 3' end pre-mRNA processing complex, such as CPSF30, Symplekin, CstF64. Y12 antibody that recognizes pre-mRNA splicing SmB/B' proteins was used as a negative control. As shown in Fig. 17 all the examined components of 3' end processing complex are associated with pre-tRNA endonuclease complexes. His-Flag-Sen2ΔEx8 is strongly  
30    associated with CPSF30, Symplekin, CstF64 suggesting that Flag-Sen2ΔEx8 is largely involved in pre-mRNA processing, whereas His-Flag-Sen2WT is weakly associated with 3' end processing factors indicating that the wild type of Sen2 is mostly involved in pre-tRNA splicing.

## **5.2 Link Between Human tRNA Splicing and pre-mRNA 3'-end Formation**

### **5.2.1 Materials and Methods**

#### **5.2.1.1 Generation of stable cell lines expressing His-Flag-tagged tRNA splicing endonuclease complex subunits**

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The open reading frames of HsSen2, HsSen2deltaEx8 and HsSen34 were modified by the addition of a sequence encoding an amino-terminal peptide tag consisting of eight histidine residues and the Flag epitope. 293 cells were transfected with a plasmid encoding His-Flag-HsSen2, His-Flag-HsSen2deltaEx8 or His-Flag-HsSen34. Clones expressing the protein were selected by hygromycin-resistance.

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Human tRNA splicing endonuclease complex subunits include the proteins HsSen2 (accession number NP\_079541), HsSen34 (accession number NP\_076980), HsSen54 (accession number XP\_208944), HsSen15 (accession number NM\_052965), and HsClp1 (accession number NM\_006831). The open reading frames of HsSen2, HsSen2deltaEx8, HsSen34, HsSen54, HsSen15, and HsClp1 were generated by PCR amplification using specific primers and cloned into His-Flag-pcDNA3.1/Hygro vector. 293 cells were transfected with His-Flag-pcDNA3.1/Hygro plasmid containing the various tRNA splicing endonuclease complex subunit cDNAs in frame with the histidine and flag epitopes, and stable clones were selected by hygromycin-resistance.

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#### **5.2.1.2 Purification of the human endonuclease complex from total cell extract containing His-Flag-tagged complex subunits**

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Total cell extracts were prepared by resuspending cell pellets in buffer B (250 mM NaCl; 30 mM Tris-HCl, pH 7.0; 1 mM EDTA; 5 % glycerol; 0.1% Triton X-100; protease inhibitors (Roche, Complete Protease Inhibitor Cocktail Tablets)). Cells were sonicated 3 times for 10 seconds, followed by centrifugation at 15,000 g for 15 minutes. Supernatants were passed through a 0.2 micrometer filter and added to anti-Flag beads (Sigma) pre-washed with buffer B. Extracts were incubated with anti-Flag beads for 2 hours at 4°C. Supernatants were discarded and beads were washed 3 times for 10 minutes at 4°C with ten bed volumes of buffer W (400 mM NaCl; 30 mM Tris-HCl, pH 7.0; 1 mM EDTA; 5% glycerol; 0.04% Triton X-100). Following two washes with ten bed volumes of buffer N (200 mM NaCl; 40 mM Tris-HCl, pH 7.0; 2 mM MgCl<sub>2</sub>; 5% glycerol; 0.05% Triton X-100), bound proteins were eluted with three bed volumes of buffer N containing 0.25 mg/ml 3xFlag peptide (Sigma) for 1 h at 4°C.

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Following addition of NaCl (final concentration of 480 mM), eluted proteins were added to Ni-beads pre-washed with buffer NBW (500 mM NaCl; 40 mM Tris-HCl, pH 7.0; 2 mM MgCl<sub>2</sub>; 5% glycerol; 0.05% triton X-100) and incubated for 1 hour at 4°C. Supernatants were discarded and Ni-beads were washed three times with ten bed volumes of buffer NB (200 mM NaCl; 40 mM Tris-HCl, pH 7.0; 2 mM MgCl<sub>2</sub>; 5% glycerol; 0.05% Triton X-100, 15 mM imidazole) for 10 minutes at 4°C. Bound proteins were eluted with three bed volumes of buffer NE (200 mM NaCl; 40 mM Tris-HCl, pH 7.0; 2 mM MgCl<sub>2</sub>; 5% glycerol; 0.05% Triton X-100, 250 mM imidazole), and equal amount of 80% glycerol was added to eluted proteins. The purified proteins were stored at -20°C.

### 10                    **5.2.1.3    Immunofluorescence microscopy**

HeLa cells were grown on glass coverslips, then were briefly washed with PBS, fixed in 2% formaldehyde/PBS for 20 minutes at room temperature and permeabilized in 0.5% Triton X-100/PBS for 5 minutes at room temperature. Fixed cells were blocked in 3% bovine serum albumin for 1 hour at room temperature. Immunofluorescence staining was performed by incubating with anti-myc antibody diluted in PBS containing 3% bovine serum albumin, followed by the specific secondary antibody coupled to fluorescein isothiocyanate. All incubations were carried out at room temperature. Images were obtained using a Zeiss Axiovert 200 epi-fluorescence microscope and captured using IPLab for windows v3.6 software.

### 20                    **5.2.1.4    Mammalian cell culture, antibodies**

HeLa and 293 cells were cultured in Dulbecco's modified Eagle's medium supplemented with 10% fetal bovine serum (Invitrogen).

Antibodies used in these experiments were as follows: anti--CstF64 (kindly provided by Dr. Wilusz), anti-myc (9E10) (BD-Pharmigen), anti-Symplekin (BD-Pharmigen), Y12 (Abcam), anti-Flag (Sigma), and anti-beta-actin (Oncogene).

### 25                    **5.2.1.5    Analysis of expression profile of HsSen2deltaEx8**

In order to determine the presence of the alternatively spliced form of HsSen2 in different tissues, cDNA libraries obtained from different tissues (Clontech) were examined by PCR using the primers located outside of exon 8: (5'-gagtagctgctggtcgaggaagcg-3' (SEQ ID NO:35), 5'-gagtagctgctggtcgaggaagcg-3' (SEQ ID NO:36). To determine a profile of HsSen2deltaEx8 expression over a range of human tissues and cancer cell lines, "BD MTE Human Multiple Tissue Expression Array" (BD, Clontech) was hybridized with an



oligonucleotide specific for Exon 8 of HsSen2 (5'-gctctgggatgtttaagtatttac-3' (SEQ ID NO:37). Hybridization was carried out according to the manufacturers' instruction (BD, Clontech).

#### 5.2.1.6 Endonuclease assay

Yeast endonuclease was used as a positive control for endonuclease activity.

- 5 Purification of *S. cerevisiae* endonuclease was performed according to Trotta et al., 1997. RNA products were extracted with phenol/chloroform, separated on a 12% polyacrylamide gel containing 8M urea, dried and exposed to film.

#### 5.2.1.7 Protein sequencing

- 10 Bands of interest were excised from 10-14.5% SDS-PAGE gradient gel and submitted to the protein sequencing facility at the City of Hope (Duarte, CA) for in-gel trypsin digestion, followed by peptide sequencing according to facility protocols.

#### 5.2.1.8 Depletion of HsSen2 with small interfering RNAs (siRNA), quantitative RT-PCR analysis and ribonuclease protection assays (RPA).

- 15 Two 19-base oligonucleotides (sense and antisense) corresponding to either exon 8 (siRNA-A) or exon 9 (siRNA-B) of the open reading frame of SEN2 were designed using "siRNA Design Guidelines" (Ambion). The oligonucleotides were annealed and cloned into the pSilencer 2.0-U6 vector (Ambion). 293 cells were transfected using Fugene 6 (Roche) with this vector encoding either the SEN2 specific sequence (siRNA-A or siRNA-B) or an irregular
- 20 control sequence (Ambion). Five separate transfections were carried out for each siRNA species. Pools of stably expressing cell lines (designated A1-5 or B1-5) were selected using 200 microgram/ml hygromycin for thirty days followed by passage into 6-well dishes for either: (a) transfection of His-Flag-HsSen2 or His-Flag-HsSen2deltaEx8 followed in 3 days by addition of 2X SDS load-dye, fractionation by SDS-PAGE, and western blot detection using anti-Flag Ab
- 25 (Sigma; 1:500) or anti-actin Ab (Oncogene; 1:2000); or (b) extraction of total RNA using Trizol (Sigma) according to the manufacturers' protocol. Total RNA was used for quantitative RT-PCR analysis. RNA (5-10 micrograms) was treated with DnaseI followed by reverse transcription performed using a RETROscript kit (Ambion). Quantative PCR was carried out using a DNA Engine Opticon 2 (MJ Research) with the following oligonucleotides: precursor
- 30 tRNA<sup>Leu</sup> (5'-gtcaggatggccgagtggtc-3' (SEQ ID NO:13); 5'-ccgaacacaggaagcagtaa-3' (SEQ ID NO:14)); tRNA<sup>Ile</sup> (5'-cggtacttataagacagtgc-3' (SEQ ID NO:15), 5'-gctccaggtgaggcttgaac-3'

(SEQ ID NO:16)), 3' UTR of GAPDH (5'-ccagcaagagcacaagag-3' (SEQ ID NO:17); 5'-tgaggaggggagattcagt-3' (SEQ ID NO:18)); sequence downstream of the AAUAAA cleavage and polyadenylation signal of GAPDH (5'-caggtggaggaagtcagg-3' (SEQ ID NO:19); 5'-ctaaccagtcagcgtcagag3'-(SEQ ID NO:20)). Quantitation was based on normalization to 18s rRNA Amplicon.

Ten micrograms of total RNA from above was utilized in an RPA assay using RPA III kit (Ambion) as per manufacturers' protocol. Antisense riboprobe was derived from +1 to +204 downstream of the AAUAAA cleavage and polyadenylation site of the GAPDH genomic DNA sequence and +4 to +247 of EF1a genomic DNA sequences. Hybridization temperature for EF1A was 44°C and for GAPDH was 42°C.

## 5.2.2 Results

### 5.2.2.1 Human homologs of the yeast tRNA splicing endonuclease subunits

To identify human homologs of the tRNA splicing endonuclease subunits, a BLAST search of the human protein database was performed using protein sequences of all four subunits of the *S. cerevisiae* tRNA splicing endonuclease. Human homologs for three subunits, *SEN54*, *SEN2* and *SEN34* (Figure 7A, 6A and B), but were unable to identify a human homolog of yeast *SEN15*. Human Sen54 (HsSen54) has a predicted molecular mass of 58 kDa and amino acid conservation between the yeast and human Sen54p was restricted to the amino- and carboxyl-terminal regions of the protein (Figure 7A). Human Sen2 (HsSen2) is predicted to be 51 kDa, larger than its yeast counterpart, and shows a high degree of similarity only in the active-site domain (Figure 6A). Conversely, the yeast and human Sen34 (Figure 6B) are highly homologous throughout the entire protein. Importantly, sequence alignments between yeast and human Sen2 and Sen34, the two subunits harboring the endonuclease active sites (Trotta et al., 1997), demonstrate the highest degree of similarity in the region corresponding to the active sites of Sen2 and Sen34. These findings indicate a remarkable conservation between the yeast and human tRNA splicing endonuclease active-site subunits.

### 5.2.2.2 The human Sen2 transcript is alternatively spliced to form at least two distinct protein products

To demonstrate that the putative human *SEN2* and *SEN34* genes encode subunits of the tRNA splicing endonuclease complex the human *SEN2* and *SEN34* cDNAs were isolated.

Surprisingly, sequencing of *SEN2* clones produced by PCR amplification from human cDNA libraries identified a variant that lacked 57 nucleotides. This deletion corresponds precisely to exon 8 of the *SEN2* genomic DNA sequence (Figure 12), demonstrating that this was an alternatively spliced form of *SEN2*.

5        PCR analysis of cDNA libraries obtained from different human tissues using oligonucleotides flanking exon 8 and monitored the presence of either full-length *SEN2* or *SEN2* lacking exon 8 (*HsSen2deltaEx8*) was performed. All tissues examined harbored both isoforms of *SEN2* (data not shown). Using a human multiple tissue expression array, we profiled the expression of *HsSen2* and *HsSen2deltaEx8* RNAs in human tissues and cancer cell  
10    lines. Northern blot analysis was performed with oligonucleotides specific for either *SEN2* or *SEN2deltaEx8*. The results demonstrated that both mRNAs are ubiquitously expressed at very low levels in all tissue types (data not shown).

#### 5.2.2.3    The human endonuclease forms two functionally distinct isoforms

15        To determine whether the human homologs of the yeast endonuclease subunits function as part of a tRNA splicing complex, a method was developed for the purification of the endonuclease complex from human cells (see Experimental Procedures). A stable 293 cell lines expressing His-Flag-tagged human homologs of the active-site subunits, *HsSen2* or *HsSen34*, as well as the alternatively spliced subunit, *HsSendeltaEx8* was generated. Proteins from total cell  
20    extracts of the stable cell lines were purified by affinity chromatography using anti-FLAG M2 affinity resin followed by Ni-NTA agarose resin. Bound proteins were eluted with imidazole and tested for ability to cleave yeast pre-tRNA<sup>Phe</sup>. The results demonstrated that protein complexes isolated from cells expressing either His-Flag-*HsSen2* or His-Flag-*HsSen34* accurately cleaved pre-tRNA<sup>Phe</sup> to yield 5' exon, 3' exon and intron (Figure 15, lanes 4 and 5).  
25    The efficiency of cleavage was similar to that of yeast tRNA splicing endonuclease (Figure 15, compare lane 4 and 5 with lane 2). Purification of cleavage activity was dependent upon expression of an epitope-tagged subunit, as proteins purified from untransfected 293 cells did not cleave pre-tRNA (Figure 15, lane 1). Taken together, these results clearly demonstrate that *HsSen2* and *HsSen34* are orthologs of the yeast tRNA splicing endonuclease subunits and that  
30    the enzyme for cleavage of pre-tRNA is evolutionarily conserved.

The endonuclease complex harboring the His-Flag-*HsSen2deltaEx8* subunit was also purified from human cells as described above. Surprisingly, the His-Flag-*HsSen2deltaEx8*-containing complex retained the ability to cleave precursor tRNA, but the fidelity and accuracy

of cleavage was severely compromised resulting in cleavage at only the 3' splice site. Moreover, the HsSen2deltaEx8-containing complex was unable to release the intron from the pre-tRNA (Figure 15, lane 3). In addition, there was a minor cleavage event within the intron of tRNA<sup>Phe</sup> resulting in two products migrating at approximately 53 and 42 nucleotide position (Figure 15, lane 3, asterisks). This minor cleavage product is not detected with other precursor tRNAs (data not shown). Thus, pre-tRNA is the endogenous substrate for the HsSen2-containing complex, but not for the HsSen2deltaEx8-containing complex. This important observation suggests that the gene for the human endonuclease subunit *SEN2* can encode two distinct active-site-containing proteins, each with different RNA cleavage specificities.

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#### 5.2.2.4 Localization of the human tRNA splicing endonuclease subunits

The subcellular localization of the human tRNA splicing endonuclease subunits was determined by microscopy. Constructs encoding various epitope-tagged subunits of the human endonuclease were transiently transfected into HeLa cells and analyzed by immunofluorescence. The results demonstrated that both active-site subunits, HsSen2 and HsSen34, as well as HsSen2deltaEx8, were exclusively localized in the nucleus (Figure 26). Interestingly, both HsSen2deltaEx8 and HsSen34 were frequently found in nucleoli in dot-like structures (Figure 26, arrowheads).

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#### 5.2.2.5 Identification of the components of the human endonuclease complexes

The results described above identified two endonuclease complexes with distinct RNA substrate specificities. To demonstrate that these complexes may also have distinct subunits with different functions the composition of both endonuclease isoforms was analyzed by SDS-PAGE and silver staining.

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This analysis identified an 18 kDa protein present in a similar stoichiometry to other components in HsSen2 and HsSen34 complexes (Figure 27A and 27B, band 1). The level of this protein was drastically reduced in HsSen2deltaEx8 purified complexes (Figure 27B). Peptides derived from this band matched an 18 kDa protein encoded by a gene located on chromosome 1 (NP 443197). Amino acid sequence alignment to yeast Sen15 revealed a previously unobserved high degree of similarity to yeast Sen15p, strongly suggesting that the protein is a human homolog of yeast Sen15p (Figure 7B).

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To confirm that HsSen15 is a subunit of the human tRNA splicing endonuclease, stable cell lines expressing epitope-tagged HsSen15 were generated and purified complexes were tested for endonucleolytic activity as described above. As shown in Figure 4D, the results demonstrated that the His-Flag-HsSen15 complex accurately cleaved precursor-tRNA<sup>Phe</sup> releasing the intron and the 5' and 3' exons. The efficiency of cleavage was similar to that of endonuclease purified from His-Flag-HsSen2 and His-Flag-HsSen34 cell lines (Figure 15), demonstrating that HsSen15 is a component of human tRNA splicing endonuclease. Taken together, these results indicate that the human tRNA splicing endonuclease complex containing HsSen2 has a simple protein composition comprised of homologs to yeast tRNA splicing endonuclease.

Analysis of the protein composition of the three complexes, HsSen2, HsSen34 and HsSen2deltaEx8, revealed two proteins in common (Figure 27A and 27B). As determined by mass spectrometry, one of these proteins co-migrates with tagged HsSen2 and HsSen2deltaEx8 and represents the human homolog of the yeast Sen54 protein (Figure 6A). The deletion of exon 8 did not effect the association of HsSen2deltaEx8 with the HsSen54 subunit (Figure 27B). A protein complex purified via tagged HsSen54 (Figure 27D) contains HsSen2, HsSen34 and HsSen15 endonuclease subunits in stoichiometric amounts. The His-Flag-HsSen54 complex accurately cleaves pre-tRNA releasing intron and two exons. These results demonstrate that HsSen54 is an intrinsic subunit of the human tRNA splicing endonuclease.

In addition to the bands described above, it is evident from silver-stained gel in Figure 27D, that there is an excess of the protein found in band 2. This band, present in endonuclease complexes purified from all four tagged subunits (Figure 27 panel A, B and D), was identified by mass spectrometry. The results identified this as the human Clp1 protein (HsClp1). This result was surprising since HsClp1 was originally isolated as a component of the cleavage factor II<sub>m</sub> (CF II<sub>m</sub>) known to be involved in the cleavage of pre-mRNA in the cleavage/polyadenylation reaction (de Vries et al., 2000).

#### **5.2.2.6 Endonuclease complexes are associated with pre-mRNA 3'-end processing machinery**

Identification of a pre-mRNA cleavage/polyadenylation protein associated with the tRNA splicing endonuclease demonstrated that the endonuclease complex are involved in multiple RNA processing events. To show that HsClp 1 is a *bona fide* component of the human tRNA splicing endonuclease, proteins purified with His-Flag-HsClp1 were isolated and analyzed

by SDS-PAGE and silver staining. Remarkably, a protein pattern that was almost identical to that of complexes purified by the tagged versions of HsSen2, HsSen34 and HsSen15 was observed (Figure 28A). This result clearly demonstrates that HsClp1 is an integral component of the human tRNA splicing endonuclease complex.

5        The complex purified with tagged-HsClp1 for tRNA endonucleolytic activity was analyzed. As shown in Figure 28B, the purified complex accurately cleaved precursor-tRNA<sup>Phe</sup> releasing the intron, and the 5' and 3' exons. The efficiency of cleavage was similar to that of complexes purified with His-FlagHsSen2 and His-Flag-HsSen34 (Figure 15). Therefore, in addition to its role in pre-mRNA 3'-end formation, HsClp1 is associated with the human tRNA  
10        splicing endonuclease.

      The results described above demonstrate that an endonuclease that forms distinct complexes with diverse RNA endonuclease activities had been identified. To identify the complexe(s) that are involved in mRNA 3'-end formation, the presence of additional components of pre-mRNA 3'-end processing machinery in the complexes was demonstrated.  
15        Complexes purified using the different epitope-tagged subunits of the endonuclease complexes were analyzed by Western blotting using antibodies specific for Symplekin and CstF64, components of the human pre-mRNA 3'-end processing complex. Y12 antibody (known to recognize pre-mRNA splicing snRNP SmB/B' proteins) was used as a negative control. Remarkably, the results (Figure 29) demonstrate that all examined components of the pre-  
20        mRNA 3'-end processing complex were associated with pre-tRNA endonuclease complexes. Similar amounts of 3'-end complexes were purified from all His-Flag-tagged tRNA endonuclease subunits. Since the purification conditions were very stringent and utilized two affinity chromatography steps (see experimental procedures), the interaction between tRNA splicing endonuclease and pre-mRNA 3'-end processing factors is quite robust.  
25        Immunoprecipitation under standard salt conditions to more accurately determine the amount of 3'-end factors associated with the tRNA endonuclease was also performed. It was shown that as much as 1% of the 3'-end processing factors are associated with the tRNA endonuclease. Since endonuclease is a very low abundance protein, this suggests that a large portion of the tRNA splicing endonuclease is associated with pre-mRNA 3'-end formation complexes within human  
30        cells. Furthermore, His-Flag-HsSen2deltaEx8 and His-Flag-HsClp1 were able to associate with a larger proportion of the 3'-end formation complexes (Figure 29, compare lane 8 and 11 to 7, 9, 10).

### 5.2.2.7 Depletion of SEN2 causes defects in tRNA splicing and pre-mRNA 3' end formation

The results described above demonstrate a biochemical link between tRNA splicing and pre-mRNA cleavage and polyadenylation. One theory is that if one of the endonuclease  
5 complexes were involved in mRNA 3' processing, then reduction in the amount of the endonuclease would result in defects in both pre-tRNA splicing and pre-mRNA 3'-end processing. To test this hypothesis the intracellular level of HsSen2 and HsSen2deltaEx8 were depleted by siRNA targeting. It was found that depletion of the SEN2 gene products by approximately 50% (Figure 30A) caused an increase in the level of pre-tRNA<sup>Leu</sup> and pre-tRNA<sup>Ile</sup>  
10 in comparison to a control siRNA (Figure 30B). This result is consistent with a role for HsSen2 in processing of pre-tRNA. Furthermore, using two independent methods, quantitative RT-PCR and ribonuclease protection (RPA), a dramatic increase in the level of GAPDH RNA containing extended sequence 3' of the cleavage and polyadenylation signal was observed (Figure 30B-C). In addition, a similar increase in the level of EF1A RNA containing 3'-extended sequence was  
15 observed (Figure 30C, top panel). These results were observed with several siRNAs that targeted different regions of HsSen2/HsSen2deltaEx8, and thus are attributable to knockdown of the SEN2 gene products and not an off-target siRNA effect (Figure 30; data not shown). Taken together, this is strong evidence that the active-site subunit HsSen2 or its spliced-variant HsSen2deltaEx8 are involved in processing of pre-tRNA and pre-mRNA, linking two  
20 fundamental processes of RNA maturation. Primers that were used in connection with the siRNA experiments are shown in Figure 30D.

### 5.2.3 Discussion

All living organisms contain a population of precursor tRNAs which are interrupted by  
25 introns. Therefore, intron removal from pre-tRNAs (*i.e.* endonuclease cleavage) is a fundamental biological process. Although intron removal from pre-tRNA has been studied in detail in the yeast *Saccharomyces cerevisiae*, the machinery for human pre-tRNA intron removal was previously unknown. The results presented here define the components of the human tRNA endonuclease complex and raise the exciting possibility that the catalytic subunits of the tRNA  
30 endonuclease can function in distinct RNA processing events.

#### 5.2.3.1 Identification of the human tRNA splicing endonuclease subunits

The protein composition, localization and function of the human tRNA splicing endonuclease has been determined as described herein. The enzyme was initially isolated using

epitope-tagged human homologs of the two active-site subunits of yeast tRNA endonuclease. These purified complexes were demonstrated herein to accurately processed precursor tRNA, cleaving at the 5' and 3' splice sites to release the intron. This result strongly suggests that HsSen2 and HsSen34 are the orthologs of the active-site subunits of tRNA splicing endonuclease. The protein composition of the tRNA splicing endonuclease was also identified as described herein. The complex is comprised of orthologs of the yeast enzyme subunits, Sen2p, Sen34p, Sen15p, and Sen54p. An unanticipated result was the finding that HsClp1, a protein involved in pre-mRNA 3'-end processing, is also an integral member of the human tRNA endonuclease complex.

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### 5.2.3.2 Model for the human tRNA splicing endonuclease

A model of the architecture of yeast tRNA endonuclease was based on the structure of archaeal endonuclease from *M. jannaschii* (Li et al., 1998). The yeast enzyme was proposed to be a heterotetramer composed of two dimers, Sen54p-Sen2p and Sen34p-Sen15p, each containing a distinct active site. Tetramerization is thought to occur by interaction of the acidic residues within loop L10 of the Sen54p and Sen15p subunits, with a polar groove formed between the amino- and carboxyl-terminal domain of the active-site endonuclease subunits (Li et al., 1998). Figure 1C and 4C show that the most conserved regions of HsSen54 and HsSen15 are located in the carboxyl-terminal region of the proteins and correspond exactly to yeast loop L10 and beta 9 sequences.

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### 5.2.3.3 Identification of an alternatively spliced isoform of HsSen2

Our investigation of the human endonuclease complex resulted in the discovery of an alternatively spliced isoform of the SEN2 active-site subunit lacking exon 8. The amino acid sequence of exon 8 corresponds to a conserved alpha2-helix found in archaeal and yeast endonucleases (Figure 6A) and is a key structural element in the formation of the tetrameric enzyme. The alpha2-helix serves to orient the amino- and carboxyl-terminal domains of the active-site subunit to allow formation of the polar groove into which the conserved loop L10 from a heterologous subunit can interact (Figure 6A; Li et al., 1998; Bujnicki and Rychlewski, 2000; Lykke-Andersen and Garrett, 1997). Thus, one theory is that omission of this alpha2-helix in HsSen2deltaEx8 would alter the structure of this active-site subunit resulting in an inability to stably interact with loop L10 of the HsSen15/HsSen34 heterodimer. Consistent with

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this theory, analysis of the composition of the HsSen2deltaEx8 complex revealed a significant reduction in the level of HsSen15 and HsSen34 protein compared to the purified HsSen2 complex (Figure 27B). This observation provides additional support for the structural model of the human and yeast tRNA splicing endonucleases.

5           Furthermore, these results raise the intriguing possibility that alteration of subunit interactions through alternative splicing is a strategy used by higher eukaryotes to generate multiple endonuclease complexes capable of different RNA processing events. This theory is supported by the result that HsSen2deltaEx8-containing endonuclease complex does not properly cleave pre-tRNAs, although it does retain endonucleolytic activity (Figure 15, lane 3).  
10       Thus, it is likely that the HsSen2deltaEx8 complex is not a tRNA splicing endonuclease, but is responsible for processing as yet unknown RNA substrates.

#### **5.2.3.4   Localization of the tRNA splicing endonuclease**

15           In this study, it was shown that the active-site subunits HsSen2 and HsSen34 localize exclusively to the nucleus, consistent with previous results suggesting that tRNA maturation occurs in the nucleus in higher eukaryotes. For example, RNase P was shown to localize to the nucleoplasm with transient association in the nucleolus in HeLa cells (Jacobson et al., 1997). Additionally, human tRNA splicing endonuclease activity behaves as a soluble nuclear protein in HeLa cells (Laski et al., 1983; Standring et al., 1981). Finally, in *Xenopus laevis*, intron-  
20       containing tRNAs are matured and modified in the nucleus and the endonuclease is a soluble protein found in the germinal vesicle of the oocyte (De Robertis and Olson, 1979; Otsuka et al., 1981; Mattoccia et al., 1979). In addition to the localization of the endonuclease subunits, a large portion of the tRNA splicing endonuclease is found associated with the nuclear-localized proteins of the mRNA 3'-end formation machinery. Taken together these data strongly support  
25       a model whereby tRNA splicing occurs in the nucleus of higher eukaryotes. This is consistent with the model for yeast tRNA splicing supported by localization of the endonuclease to the nuclear membrane fraction (Peebles et al., 1983; Rauhut et al., 1990) and immuno-localization of the yeast tRNA splicing ligase, which joins the 5' and 3' exons of tRNA after endonucleolytic cleavage, to the inner membrane of the nuclear envelope (Clark and Abelson, 1987).

30           Recently two pieces of evidence have emerged suggesting that tRNA splicing in yeast occurs in the cytoplasm. Yoshihisa and colleagues demonstrated that a fraction of tRNA endonuclease is found associated with the mitochondrial surface and that temperature-sensitive mutations of the tRNA splicing endonuclease accumulated intron-containing tRNA in the

cytosol (Yoshihisa et al., 2003). Furthermore, analysis of a genome-wide GFP-fusion localization study indicated that GFP-tagged subunits of the endonuclease, ySen2, ySen54 and ySen15 localize exclusively to the mitochondria (Huh et al., 2003). In addition, a GFP-tagged fusion to tRNA splicing ligase localizes throughout the cytoplasm. Taken together, these observations are consistent with a model whereby tRNA splicing occurs within the cytoplasm in yeast. This model contrasts with the nuclear localization of the human enzyme that we have presented in this paper. Thus, it appears as though tRNA splicing localization may be regulated differently in yeast and humans. Consistent with our findings in HeLa cells we also found that GFP-tagged HsSen2 and HsSen34 localized to the nucleus in primary neurons (data not shown).

The active-site subunits can localize in dot-like structures within the nucleolus (Figure 26, arrowheads). This suggests the possibility that the tRNA splicing endonuclease may be transiently localized in the nucleolus. In preliminary experiments, treatment of HeLa cells with Actinomycin D altered the localization of GFP-tagged HsSen2 or HsSen34 within the nucleus, leading to diffuse localization in both the nucleoplasm and the nucleolus (data not shown). This suggests that tRNA splicing endonuclease can cycle between the nucleoplasm and the nucleolus. This observation may have important implications for the regulation of the tRNA splicing in higher eukaryotes.

#### **5.2.3.5 The endonuclease provides a biochemical link between tRNA splicing and pre-mRNA 3'-end formation**

The demonstration of a role for HsClp1 in splicing of tRNA precursors is surprising and suggests a link between the processes of tRNA splicing and mRNA 3'-end formation. Keller and co-workers originally identified the HsClp1 protein as a component of CF II<sub>m</sub> known to be involved in 3'-end processing of pre-mRNA (de Vries et al., 2000). Generation of the 3' end of pre-mRNA is thought to be a two-step reaction, whereby pre-mRNA is endonucleolytically cleaved and subsequently polyadenylated to yield a mature mRNA. The pre-mRNA 3'-end processing complex consists of cleavage and polyadenylation specificity factor (CPSF), cleavage stimulation factor (CstF), two cleavage factors, CF I<sub>m</sub> and CF II<sub>m</sub>, and poly(A) polymerase (PAP) (reviewed in Wahle and Ruegsegger, 1999; Calvo and Manley, 2003; Zhao et al., 1999a). HsClp1 has been shown to be a subunit of CF II<sub>m</sub> and is thought to act as a bridge, as it interacts with CF I<sub>m</sub> and CPSF (de Vries et al 2000). In yeast, Clp1 has also been shown to be involved in 3'-end processing (Minvielle-Sebastia and Keller, 1999).

Several pieces of evidence have been previously reported that are consistent with a link between tRNA processing and pre-mRNA 3'-end formation. O'Connor and Peebles demonstrated that yeast containing a conditional *pta1* allele were defective in the processing of precursor tRNAs (O'Connor and Peebles, 1992). Subsequently, Pta1p was identified as a component of the yeast pre-mRNA 3'-end processing machinery (Preker et al., 1997; Zhao et al., 1999b). The human homolog of *PTA1*, symplekin, was found to be associated with cleavage stimulation factor (CstF) (Takagaki and Manley, 2000; Zhao et al., 1999b). Additionally, pre-tRNA 3'-end processing and pre-mRNA 3'-end formation have been genetically linked in humans. Takaku et al., have shown that ELAC2 is the enzyme responsible for 3'-end processing of precursor tRNA transcripts (Takaku et al., 2003; Zhao et al., 1999b; Takaku et al., 2003). Prior work showed that ELAC2 has a high degree of similarity with CPSF73, a protein belonging to the pre-mRNA cleavage and polyadenylation specificity factor (Simard et al., 2002; Tavtigian et al., 2001), suggesting that CPSF73 may be an endonuclease involved in pre-mRNA 3'-end processing. Thus, it is possible that the machinery (ie., endonuclease) for these disparate RNA processes, pre-tRNA splicing, pre-tRNA 3'-end maturation and pre-mRNA 3'-end formation, all arose from a common ancestor. This paradigm is supported by the notion that the tRNA splicing endonuclease is an ancient RNA processing enzyme (Belfort and Weiner, 1997; Trotta and Abelson, 1998).

This is the first demonstration of a biochemical link between pre-tRNA processing and pre-mRNA 3'-end processing. It has been shown herein that HsClp1 is a subunit of two distinct human endonuclease complexes: an HsSen2 tRNA splicing endonuclease complex and an endonuclease complex formed by the alternatively spliced form of *SEN2*, HsSen2deltaEx8. Remarkably, the tRNA endonuclease that co-purified with tagged-HsClp1 cleaves precursor tRNA specifically at the 5' and 3' splice sites to release the intron, suggesting that the HsClp1 protein is strongly associated with the machinery for cleavage of precursor tRNAs in human cells.

In addition, that the human endonuclease complexes was found to associate with a subset of 3'-end processing factors that include CPSF160, CPSF30, CstF64, symplekin, but not PAP and Sm proteins (Figure 29 and data not shown). This specific set of protein components suggests that endonuclease complexes may be involved in the cleavage of pre-mRNA, as opposed to splicing or polyadenylation. Interestingly, the HsSen2deltaEx8 complex more strongly associated with Symplekin, and CstF64 than the HsSen2 complex. The significance of the tighter association between alternatively spliced *SEN2* and pre-mRNA 3'-end processing is unknown, but the altered substrate specificity in cleavage reactions and the presence of pre-

mRNA 3'-end processing factors in purified fractions suggest that HsSen2deltaEx8 may be primarily involved in processing of pre-mRNA. Consistent with this theory, siRNA depletion of the products of the *SEN2* gene resulted in defects in 3'-end processing of endogenous mRNA transcripts, causing the accumulation of end-extended products, as detected by both quantitative  
5 RT-PCR and ribonuclease protection assays for several different mRNA transcripts (Figure 30A-C). As shown in Figure 30, an attempt was made to distinguish the roles of wild-type Sen2 versus HsSen2deltaEx8 in processing pre-tRNA and pre-mRNA 3' ends by specifically targeting wild-type HsSen2 with siRNA-A, but for unknown reasons this siRNA caused the depletion of both versions of *SEN2*.

10 Taken together, the *SEN2* siRNA targeting results and the evidence of a physical association between the two machineries described above, support a model whereby tRNA splicing and pre-mRNA 3'-end formation are catalyzed by the same components of an endonuclease complex in mammalian cells. This suggests that this endonuclease complex functions in the formation of mRNA, tRNA, and potentially other RNA substrates. The concept  
15 of coupling pre-tRNA splicing to the formation of the 3' end of mRNAs is interesting because it could allow cells to modulate the level of mature mRNA by sensing the amount of pre-tRNA that is produced in response to various growth conditions. This is the first example of regulating translation efficiency by a complex that controls multiple RNA processing activities in the cell.

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Equivalents:

The present invention is not to be limited in scope by the specific embodiments described herein. Indeed, various modifications of the invention in addition to those described will become apparent to those skilled in the art from the foregoing description and  
5 accompanying figures. Such modifications are intended to fall within the scope of the appended claims.

Various publications are cited herein, the disclosures of which are incorporated by reference in their entireties.

**WHAT IS CLAIMED IS:**

1. A purified complex, wherein the complex comprises:
  - (i) Sen2 (ACCESSION NO.: NP\_079541), or a protein encoded by a nucleic acid that hybridizes to the Sen2 encoding nucleic acid (ACCESSION NO.: NM\_025265) or its complement under high stringency conditions;
  - (ii) Sen15 or a protein encoded by a nucleic acid that hybridizes to the Sen15 encoding nucleic acid (ACCESSION NO.: NM\_052965) or its complement under high stringency conditions;
  - (iii) Sen34 (ACCESSION NO.: NP\_076980), or a protein encoded by a nucleic acid that hybridizes to the Sen34 encoding nucleic acid (ACCESSION NO.: NM\_024075) or its complement under high stringency conditions; and
  - (iv) Sen54 (ACCESSION NO.: XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the Sen54 encoding nucleic acid (ACCESSION NO.: XM\_208944) or its complement under high stringency conditions,
- 15 wherein said high stringency conditions comprise hybridization in a buffer consisting of 6X SSC, 50 mM Tris-HCl (pH=7.5), 1 mM EDTA, 0.02% PVP, 0.02% Ficoll, 0.02% BSA and 100 µg/ml denatured salmon sperm DNA, for 48 hours at 65°C, washing in a buffer consisting of 2X SSC, 0.01% PVP, 0.01% Ficoll and 0.01% BSA, for 45 minutes at 37°C, and washing in a buffer consisting of 0.1X SSC, for 45 minutes at 50°C.
- 20 2. The complex of claim 1, wherein the complex further comprises Clp1 (ACCESSION NO.: NP\_006822) or a protein encoded by a nucleic acid that hybridizes to the Clp1 encoding nucleic acid (ACCESSION NO.: NM\_006831) or its complement under high stringency conditions.
- 25 3. The complex of claim 2, wherein the complex further comprises one or more of the following:
  - (i) Cleavage-Polyadenylation Specificity Factor or proteins encoded by nucleic acids that hybridize to the Cleavage-Polyadenylation Specificity Factor encoding nucleic acids or their complements under high stringency conditions;

- (ii) Cleavage Factor I<sub>m</sub> or proteins encoded by nucleic acids that hybridize to the Cleavage Factor I<sub>m</sub> encoding nucleic acids or their complements under high stringency conditions;
- (iii) Cleavage Factor II<sub>m</sub> or proteins encoded by nucleic acids that hybridize to the Cleavage Factor II<sub>m</sub> encoding nucleic acids or their complements under high stringency conditions; and
- (iv) Cleavage Stimulation Factor or proteins encoded by nucleic acids that hybridize to the Cleavage Stimulation Factor encoding nucleic acids or their complements under high stringency conditions.
4. The complex of claim 2, wherein the complex further comprises one or more of the following:
- (i) CPSF160 or a protein encoded by a nucleic acid that hybridizes to CPSF160 encoding nucleic acid or its complement under high stringency conditions;
- (ii) CPSF30 or a protein encoded by a nucleic acid that hybridizes to CPSF30 encoding nucleic acid or its complement under high stringency conditions;
- (iii) CstF64 or a protein encoded by a nucleic acid that hybridizes to CstF64 encoding nucleic acid or its complement under high stringency conditions;
- (iv) symplekin or a protein encoded by a nucleic acid that hybridizes to symplekin encoding nucleic acid or its complement under high stringency conditions
5. A purified complex comprising Sen2deltaEx8, or a protein encoded by a nucleic acid that hybridizes under stringent hybridization conditions to a Sen2deltaEx8 encoding nucleic acid.
6. A purified complex, wherein the complex comprises:
- (i) Sen2deltaEx8 (SEQ ID NO.: 2), or a protein encoded by a nucleic acid that hybridizes to the Sen2deltaEx8 encoding nucleic acid (SEQ ID NO.: 1) or its complement under high stringency conditions; and
- (ii) Sen54 (ACCESSION NO.:XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the Sen54 encoding nucleic acid (ACCESSION NO.:XM\_208944) or its complement under high stringency conditions;

wherein said high stringency conditions comprise hybridization in a buffer consisting of 6X SSC, 50 mM Tris-HCl (pH=7.5), 1 mM EDTA, 0.02% PVP, 0.02% Ficoll, 0.02% BSA and 100 µg/ml denatured salmon sperm DNA, for 48 hours at 65°C, washing in a buffer consisting of 2X SSC, 0.01% PVP, 0.01% Ficoll and 0.01% BSA, for 45 minutes at 37°C, and washing in a  
5 buffer consisting of 0.1X SSC, for 45 minutes at 50°C.

7. The purified complex of claim 6, wherein the complex further comprises: Clp1 (ACCESSION NO.:NP\_006822) or a protein encoded by a nucleic acid that hybridizes to the Clp1 encoding nucleic acid (ACCESSION NO.: NM\_006831) or its complement under high stringency conditions.

10 8. The purified complex of claim 7, wherein the complex further comprises one or more of the following:

(i) Cleavage-Polyadenylation Specificity Factor or proteins encoded by nucleic acids that hybridize to the Cleavage-Polyadenylation Specificity Factor encoding nucleic acids or their complements under high stringency conditions;

(ii) Cleavage Factor I<sub>m</sub> or proteins encoded by nucleic acids that hybridize to the Cleavage Factor I<sub>m</sub> encoding nucleic acids or their complements under high stringency conditions;

(iii) Cleavage Factor II<sub>m</sub> or proteins encoded by nucleic acids that hybridize to the Cleavage Factor II<sub>m</sub> encoding nucleic acids or their complements under high stringency conditions; and

(iv) Cleavage Stimulation Factor or proteins encoded by nucleic acids that hybridize to the Cleavage Stimulation Factor encoding nucleic acids or their complements under high stringency conditions.

25 9. A purified complex, wherein the complex comprises:

(i) Sen2deltaEx8 (SEQ ID NO.: 2), or a protein encoded by a nucleic acid that hybridizes to the Sen2deltaEx8 encoding nucleic acid (SEQ ID NO.: 1) or its complement under high stringency conditions;

- (ii) Sen15 or a protein encoded by a nucleic acid that hybridizes to the Sen15 encoding nucleic acid (ACCESSION NO.:NM\_052965) or its complement under high stringency conditions;
- (iii) Sen34 (ACCESSION NO.:NP\_076980), or a protein encoded by a nucleic acid that hybridizes to the Sen34 encoding nucleic acid (ACCESSION NO.:NM\_024075) or its complement under high stringency conditions; and
- (iv) Sen54 (ACCESSION NO.:XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the Sen54 encoding nucleic acid (ACCESSION NO.:XM\_208944) or its complement under high stringency conditions,
- wherein said high stringency conditions comprise hybridization in a buffer consisting of 6X SSC, 50 mM Tris-HCl (pH=7.5), 1 mM EDTA, 0.02% PVP, 0.02% Ficoll, 0.02% BSA and 100 µg/ml denatured salmon sperm DNA, for 48 hours at 65°C, washing in a buffer consisting of 2X SSC, 0.01% PVP, 0.01% Ficoll and 0.01% BSA, for 45 minutes at 37°C, and washing in a buffer consisting of 0.1X SSC, for 45 minutes at 50°C.
10. The purified complex of claim 9, wherein the complex further comprises: Clp1 (ACCESSION NO.:NP\_006822) or a protein encoded by a nucleic acid that hybridizes to the Clp1 encoding nucleic acid (ACCESSION NO.: NM\_006831) or its complement under high stringency conditions.
11. The purified complex of claim 10, wherein the complex further comprises:
- (i) Cleavage-Polyadenylation Specificity Factor or proteins encoded by nucleic acids that hybridize to the Cleavage-Polyadenylation Specificity Factor encoding nucleic acids or their complements under high stringency conditions;
- (ii) Cleavage Factor I<sub>m</sub> or proteins encoded by nucleic acids that hybridize to the Cleavage Factor I<sub>m</sub> encoding nucleic acids or their complements under high stringency conditions;
- (iii) Cleavage Factor II<sub>m</sub> or proteins encoded by nucleic acids that hybridize to the Cleavage Factor II<sub>m</sub> encoding nucleic acids or their complements under high stringency conditions; and

(iv) Cleavage Stimulation Factor or proteins encoded by nucleic acids that hybridize to the Cleavage Stimulation Factor encoding nucleic acids or their complements under high stringency conditions.

12. The complex of claim 10, wherein the complex further comprises one or more of the following:

(i) CPSF160 or a protein encoded by a nucleic acid that hybridizes to CPSF160 encoding nucleic acid or its complement under high stringency conditions;

(ii) CPSF30 or a protein encoded by a nucleic acid that hybridizes to CPSF30 encoding nucleic acid or its complement under high stringency conditions;

10 (iii) CstF64 or a protein encoded by a nucleic acid that hybridizes to CstF64 encoding nucleic acid or its complement under high stringency conditions; and

(iv) symplekin or a protein encoded by a nucleic acid that hybridizes to symplekin encoding nucleic acid or its complement under high stringency conditions

15 13. A purified complex, wherein the complex comprises:

(i) Sen15 or a protein encoded by a nucleic acid that hybridizes to the Sen15 encoding nucleic acid (ACCESSION NO.:NM\_052965) or its complement under high stringency conditions; and

20 (ii) Sen34 (ACCESSION NO.:NP\_076980), or a protein encoded by a nucleic acid that hybridizes to the Sen34 encoding nucleic acid (ACCESSION NO.:NM\_024075) or its complement under high stringency conditions.

14. The complex of claim 1, 6, 9, or 13, wherein at least two proteins of the complex are covalently linked to each other.

25 15. The complex of claim 1, 6, 9, or 13, wherein at least two proteins of the complex are non-covalently linked to each other.

16. The complex of claim 1, 6, 9, or 13, wherein at least one protein of the complex is a functionally active derivative, wherein the functionally active derivative is a fusion protein comprising the protein fused to an amino acid sequence different from the protein.

17. The complex of claim 1, 6, 9, or 13, wherein the complex comprises at least one fragment of a protein, wherein the fragment binds to one or more other protein components of the complex.
18. An antibody or a fragment thereof that immunospecifically binds to the complex of claim 1, 6, 9, or 13 with a higher affinity than the affinity of the antibody or antibody fragment to any of the protein components of the complex.
19. An antibody or a fragment thereof that immunospecifically binds to Sen2 (Accession No.:NP\_079541), Sen15 (Accession No.:NP\_443197), Sen34 (Accession No.:NP\_076980) or Sen54 (Accession No.:XP\_208944).
20. A method for generating an antibody comprising immunizing an animal with the complex of claim 1, 6, 9, or 13.
21. A purified nucleic acid, wherein the nucleic acid encodes a protein comprising the amino acid sequence of SEQ ID NO.:12.
22. A purified nucleic acid, wherein the nucleic acid comprises the nucleic acid sequence of SEQ ID NO.:11.
23. A purified nucleic acid comprising a contiguous open reading frame which encodes a polypeptide comprising amino acid 280 to amino acid 330 of SEQ ID NO:12.
24. A purified nucleic acid which hybridizes over its full length to the complement of a nucleic acid comprising SEQ ID NO:11 under high stringency conditions, wherein said high stringency conditions comprise hybridization in a buffer consisting of 6X SSC, 50 mM Tris-HCl (pH=7.5), 1 mM EDTA, 0.02% PVP, 0.02% Ficoll, 0.02% BSA and 100 µg/ml denatured salmon sperm DNA, for 48 hours at 65°C, washing in a buffer consisting of 2X SSC, 0.01% PVP, 0.01% Ficoll and 0.01% BSA, for 45 minutes at 37°C, and washing in a buffer consisting of 0.1X SSC, for 45 minutes at 50°C.
25. The nucleic acid of claim 24, wherein the nucleic acid encodes a polypeptide that has RNA nucleolytic activity.
26. The nucleic acid of claim 22, 23, or 24, further comprising a heterologous nucleic acid sequence.
27. A vector comprising the nucleic acid of claim 21, 22, 23, or 24.
28. A host cell comprising the vector of claim 27.

29. A host cell comprising the nucleic acid of claim 21, 22, 23, or 24.
30. A method for producing a polypeptide comprising culturing the host cell of claim 28.
31. A method for producing a polypeptide comprising culturing the host cell of claim 29.
32. A purified polypeptide comprising the amino acid sequence of SEQ ID NO:12, or the  
5 amino acid sequence encoded by a nucleic acid sequence that hybridizes over its full length to the complement of SEQ ID NO:11 under high stringency conditions, wherein said high stringency conditions comprise hybridization in a buffer consisting of 6X SSC, 50 mM Tris-HCl (pH=7.5), 1 mM EDTA, 0.02% PVP, 0.02% Ficoll, 0.02% BSA and 100 µg/ml denatured salmon sperm DNA, for 48 hours at 65°C, washing in a buffer consisting of 2X SSC, 0.01%  
10 PVP, 0.01% Ficoll and 0.01% BSA, for 45 minutes at 37°C, and washing in a buffer consisting of 0.1X SSC, for 45 minutes at 50°C.
33. The polypeptide of claim 32 further comprising a heterologous amino acid sequence.
34. An antibody or fragment thereof that immunospecifically binds to the polypeptide of claim 32.
- 15 35. The antibody or antibody fragment of claim 34, wherein the antibody does not bind to Sen2 (ACCESSION NO.: NP\_079541).
36. A method for purifying the complex of claim 1, 6, 9, or 13, wherein the method comprises:
- 20 (a) preparing a cell extract or a nuclear extract from a cell, wherein the cell expresses all protein components of the complex and wherein at least one of the protein components is fused to a peptide tag; and
- (b) purifying the complex by virtue of the peptide tag.
37. A pharmaceutical composition comprising the complex of claim 1, 6, 9, or 13 and a pharmaceutically acceptable carrier.
- 25 38. A pharmaceutical composition comprising the antibody of claim 34.
39. A method of identifying a compound that modulates the formation of a complex, wherein the method comprises the following steps:
- (a) contacting a cell with a compound, wherein the cell comprises all components of the complex of claim 1, 6, 9, or 13; and



- (b) measuring the amount of the complex of formed in the cell.
40. The method of claim 39 wherein the cell is a human cell.
41. The method of claim 40, wherein the cell is a 293T, HeLa, MCF7, Wi-38, SkBr3, Jurkat, CEM, or a THP1 cell.
- 5 42. The method of claim 39, wherein the method comprises isolating the complex of claim 1, 6, 9, or 13 from the cell.
43. The method of claim 39, wherein the amount of complex is measured by FRET.
44. The method of claim 39, wherein the cell is engineered to express at least one of the protein components of the complex.
- 10 45. A method of identifying a compound that modulates the formation of a complex, wherein the method comprises the following steps:
- (a) incubating
- (i) Sen2 (ACCESSION NO.: NP\_079541), or a protein encoded by a nucleic acid that hybridizes to the Sen2 encoding nucleic acid (ACCESSION NO.: NM\_025265) or its complement under high stringency conditions;
- 15 (ii) Sen15 or a protein encoded by a nucleic acid that hybridizes to the Sen15 encoding nucleic acid (ACCESSION NO.:NM\_052965) or its complement under high stringency conditions;
- (iii) Sen34 (ACCESSION NO.:NP\_076980), or a protein encoded by a nucleic acid that hybridizes to the Sen34 encoding nucleic acid (ACCESSION NO.:NM\_024075) or its complement under high stringency conditions; and
- 20 (iv) Sen54 (ACCESSION NO.:XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the Sen54 encoding nucleic acid (ACCESSION NO.:XM\_208944) or its complement under high stringency conditions;
- 25 in the presence of a compound under conditions conducive to formation of a complex comprising the proteins; and
- (b) determining the amount of the complex,

wherein a difference in the amount of the complex determined in step (b) relative to the amount of the complex determined in the absence of the compound indicates that the compound modulates the formation of the complex.

46. The method of claim 45, wherein Clp1 (ACCESSION NO.:NP\_006822) or a protein encoded by a nucleic acid that hybridizes to the Clp1 encoding nucleic acid (ACCESSION NO.: NM\_006831) or its complement under high stringency conditions is also incubated in step (a).

47. A method of identifying a compound that modulates the formation of a complex, wherein the method comprises the following steps:

(a) incubating

10 (i) Sen2deltaEx8 (SEQ ID NO.: 2), or a protein encoded by a nucleic acid that hybridizes to the Sen2deltaEx8 encoding nucleic acid (SEQ ID NO.: 1) or its complement under high stringency conditions;

(ii) Sen15 or a protein encoded by a nucleic acid that hybridizes to the Sen15 encoding nucleic acid (ACCESSION NO.:NM\_052965) or its complement under high stringency conditions;

15 (iii) Sen34 (ACCESSION NO.:NP\_076980), or a protein encoded by a nucleic acid that hybridizes to the Sen34 encoding nucleic acid (ACCESSION NO.:NM\_024075) or its complement under high stringency conditions; and

(iv) Sen54 (ACCESSION NO.:XP\_208944), or a protein encoded by a nucleic acid that hybridizes to the Sen54 encoding nucleic acid (ACCESSION NO.:XM\_208944) or its complement under high stringency conditions;

20 in the presence of a compound under conditions conducive to formation of a complex comprising the proteins; and

(b) determining the amount of the complex,

25 wherein a difference in the amount of the complex determined in step (b) relative to the amount of the complex determined in the absence of the compound indicates that the compound modulates the formation of the complex.

48. The method of claim 47, wherein Clp1 (ACCESSION NO.:NP\_006822) or a protein encoded by a nucleic acid that hybridizes to the Clp1 encoding nucleic acid (ACCESSION NO.: NM\_006831) or its complement under high stringency conditions is also incubated in step (a).

30

49. A method of identifying a compound that modulates the stability of a complex, wherein the method comprises the following steps:

(a) incubating the complex of claim 1, 6, 9, or 13 in the presence of a compound under conditions conducive to maintaining the complex; and

5 (b) determining the amount of the complex,

wherein a difference in the amount of the complex determined in step (b) relative to the amount of the complex determined in the absence of the compound indicates that the compound modulates the stability of the complex.

50. The method of claim 45 or 46, wherein the method further comprises the step of  
10 comparing the ratio between the formed complex relative to the amount of the individual proteins.

51. The method of claim 45 or 46, wherein the proteins are incubated in step (a) in equimolar amounts.

52. A method for identifying a compound that modulates human tRNA splicing  
15 endonuclease activity, said method comprising:

(a) contacting a member of a library of compounds with a the complex of claim 1 and a nucleic acid comprising a reporter gene, wherein the reporter gene comprises a tRNA intron, and wherein all factors required for gene expression are present; and

20 (b) detecting the expression of said reporter gene, wherein a compound that modulates tRNA splicing endonuclease activity is identified if the expression of said reporter gene in the presence of a compound is altered relative to the expression of said reporter gene in the absence of said compound or the presence of a control.

25 53. A method for identifying a compound that modulates 3' end pre-mRNA endonuclease cleavage activity, said method comprising:

(a) contacting a member of a library of compounds with a the complex of claim 1 or 9 and a nucleic acid comprising a reporter gene and a cleavage site for a 3' end pre-mRNA endonuclease, wherein the reporter gene is  
30 located 3' of the cleavage site for a 3' end pre-mRNA endonuclease, and wherein all factors required for gene expression are present; and

- 5 (b) detecting the expression of said reporter gene, wherein a compound that modulates 3' end pre-mRNA endonuclease cleavage activity is identified if the expression of said reporter gene in the presence of a compound is altered relative to the expression of said reporter gene in the absence of said compound or the presence of a control.

54. A method of identifying a compound that modulates human tRNA splicing endonuclease activity, said method comprising:

- 10 (a) contacting the complex of claim 1 with a substrate of a tRNA splicing endonuclease and a member of a library of compounds, wherein the substrate is labeled at the 5' end with a fluorophore and at the 3' end with a quencher; and
- 15 (b) measuring the activity of the tRNA splicing endonuclease, wherein a compound that modulates tRNA splicing activity is identified if a fluorescent signal is altered in the presence of the compound relative to the absence of the compound or the presence of a control.

55. A method of identifying a compound that modulates human 3' end pre-mRNA endonuclease cleavage activity, said method comprising:

- 20 (a) contacting the complex of claim 1 or 9 with a substrate of a 3' end pre-mRNA endonuclease and a member of a library of compounds, wherein the substrate is labeled at the 5' end with a fluorophore and at the 3' end with a quencher; and
- 25 (b) measuring the activity of the 3' end pre-mRNA endonuclease, wherein a compound that modulates 3' end pre-mRNA endonuclease activity is identified if a fluorescent signal is altered in the presence of the compound relative to the absence of the compound or the presence of a control.

56. A method of identifying a compound that modulates human tRNA splicing endonuclease activity, said method comprising:

- 30 (a) contacting the complex of claim 1 with a substrate of a tRNA splicing endonuclease and a member of a library of compounds, wherein said

substrate is labeled at the 5' end with a fluorescent donor moiety and labeled at the 3' end with a fluorescent acceptor moiety; and

- (b) measuring the activity of the tRNA splicing endonuclease, wherein a compound that modulates tRNA splicing activity is identified if the fluorescence emission of the fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety in the presence of the compound is altered relative to the absence of the compound or the presence of a control.

57. A method of identifying a compound that modulates human 3' end pre-mRNA endonuclease cleavage activity, said method comprising:

- (a) contacting the complex of claim 1 or 9 with a substrate of a 3' end pre-mRNA endonuclease and a member of a library of compounds, wherein said substrate is labeled at the 5' end with a fluorescent donor moiety and labeled at the 3' end with a fluorescent acceptor moiety; and
- (b) measuring the activity of the 3' end pre-mRNA endonuclease, wherein a compound that modulates 3' end pre-mRNA endonuclease activity is identified if the fluorescence emission of the fluorescent acceptor moiety at the wavelength of the fluorescent donor moiety in the presence of the compound is altered relative to the absence of the compound or the presence of a control.

58. The method of claim 39, wherein the compound is tested for inhibition of the formation of the complex.

59. The method of claim 45 or 46, wherein the compound is tested for inhibition of the formation of the complex.

60. A method of treating, preventing, or managing a proliferative disorder comprising administering a pharmaceutically acceptable amount of a compound identified by the method of claim 58.

61. A method of treating, preventing, or managing a proliferative disorder comprising administering a pharmaceutically acceptable amount of a compound identified by the method of claim 59.

62. The method of claim 52, 54 or 56, wherein the compound is tested for inhibition of human tRNA splicing endonuclease activity.

63. A method of treating, preventing, or managing a proliferative disorder comprising administering a pharmaceutically acceptable amount of a compound identified by the method of claim 62.
64. The method of claim 53, wherein the compound is tested for inhibition of human 3' end pre-mRNA endonuclease activity.
65. The method of claim 55, wherein the compound is tested for inhibition of human 3' end pre-mRNA endonuclease activity
66. The method of claim 57, wherein the compound is tested for inhibition of human 3' end pre-mRNA endonuclease activity
67. A method of treating, preventing, or managing a proliferative disorder comprising administering a pharmaceutically acceptable amount of a compound identified by the method of claim 64.
68. A method of treating, preventing, or managing a proliferative disorder comprising administering a pharmaceutically acceptable amount of a compound identified by the method of claim 65.
69. A method of treating, preventing, or managing a proliferative disorder comprising administering a pharmaceutically acceptable amount of a compound identified by the method of claim 66.
70. The method of claim 52, 54 or 56, wherein the compound enhances tRNA splicing endonuclease activity.
71. The method of claim 53, wherein the compound enhances 3' end pre-mRNA endonuclease activity.
72. The method of claim 55, wherein the compound enhances 3' end pre-mRNA endonuclease activity.
73. The method of claim 57, wherein the compound enhances 3' end pre-mRNA endonuclease activity.
74. The method of claim 52, 54 or 56, wherein the method further comprises determining the structure of the compound.
75. The method of claim 53, wherein the method further comprises determining the structure of the compound.

76. The method of claim 55, wherein the method further comprises determining the structure of the compound.
77. The method of claim 57, wherein the method further comprises determining the structure of the compound.
- 5 78. The method of claim 45, 47, 52, 54, or 56, wherein the compound is selected from a combinatorial library of compounds comprising peptoids; random biooligomers; diversomers such as hydantoins, benzodiazepines and dipeptides; vinylogous polypeptides; nonpeptidal peptidomimetics; oligocarbamates; peptidyl phosphonates; peptide nucleic acid libraries; antibody libraries; carbohydrate libraries; and small organic molecule libraries.
- 10 79. The method of claim 39, wherein the compound is selected from a combinatorial library of compounds comprising peptoids; random biooligomers; diversomers such as hydantoins, benzodiazepines and dipeptides; vinylogous polypeptides; nonpeptidal peptidomimetics; oligocarbamates; peptidyl phosphonates; peptide nucleic acid libraries; antibody libraries; carbohydrate libraries; and small organic molecule libraries.
- 15 80. The method of claim 49, wherein the compound is selected from a combinatorial library of compounds comprising peptoids; random biooligomers; diversomers such as hydantoins, benzodiazepines and dipeptides; vinylogous polypeptides; nonpeptidal peptidomimetics; oligocarbamates; peptidyl phosphonates; peptide nucleic acid libraries; antibody libraries; carbohydrate libraries; and small organic molecule libraries.
- 20 81. The method of claim 53, wherein the compound is selected from a combinatorial library of compounds comprising peptoids; random biooligomers; diversomers such as hydantoins, benzodiazepines and dipeptides; vinylogous polypeptides; nonpeptidal peptidomimetics; oligocarbamates; peptidyl phosphonates; peptide nucleic acid libraries; antibody libraries; carbohydrate libraries; and small organic molecule libraries.
- 25 82. The method of claim 55, wherein the compound is selected from a combinatorial library of compounds comprising peptoids; random biooligomers; diversomers such as hydantoins, benzodiazepines and dipeptides; vinylogous polypeptides; nonpeptidal peptidomimetics; oligocarbamates; peptidyl phosphonates; peptide nucleic acid libraries; antibody libraries; carbohydrate libraries; and small organic molecule libraries.
- 30 83. The method of claim 57, wherein the compound is selected from a combinatorial library of compounds comprising peptoids; random biooligomers; diversomers such as hydantoins, benzodiazepines and dipeptides; vinylogous polypeptides; nonpeptidal peptidomimetics;

oligocarbamates; peptidyl phosphonates; peptide nucleic acid libraries; antibody libraries; carbohydrate libraries; and small organic molecule libraries.

84. The method of claim 52, 54, or 56, wherein the compound directly binds the complex.

85. The method of claim 39, wherein the compound directly binds the complex.

5 86. The method of claim 49, wherein the compound directly binds the complex.

87. A method for diagnosing a proliferative disorder in a subject, wherein the method comprises (a) contacting a sample from the subject with an antibody or fragment thereof that immunospecifically binds to a protein selected from the group selected of Sen2, Sen15, Sen34, Sen54, Clp1, SenA8Ex, CPSF, CFI<sub>m</sub>, CFII<sub>m</sub>, and CstF; and (b) detecting the antibody of  
10 fragment thereof, wherein a reduced level of the protein compared to the level of the protein in a subject without a proliferative disorder indicates that the subject has a proliferative disorder.

88. A method for diagnosing a proliferative disorder in a subject, wherein the method comprises (a) contacting a sample from the subject with an antibody or fragment thereof that immunospecifically binds to the complex of claim 1, 6, 9, or 13; and (b) detecting the antibody  
15 of fragment thereof, wherein a reduced level of the complex compared to the level of the complex in a subject without a proliferative disorder indicates that the subject has a proliferative disorder.

89. A method of cleaving an mRNA or a pre-mRNA molecule, wherein the method comprises incubating the complex of claim 1, 6, 9, or 13 with the mRNA or pre-mRNA  
20 molecule.

90. The method of claim 89, wherein the mRNA comprises a premature stop codon.



## HTS Fluorescent Screening

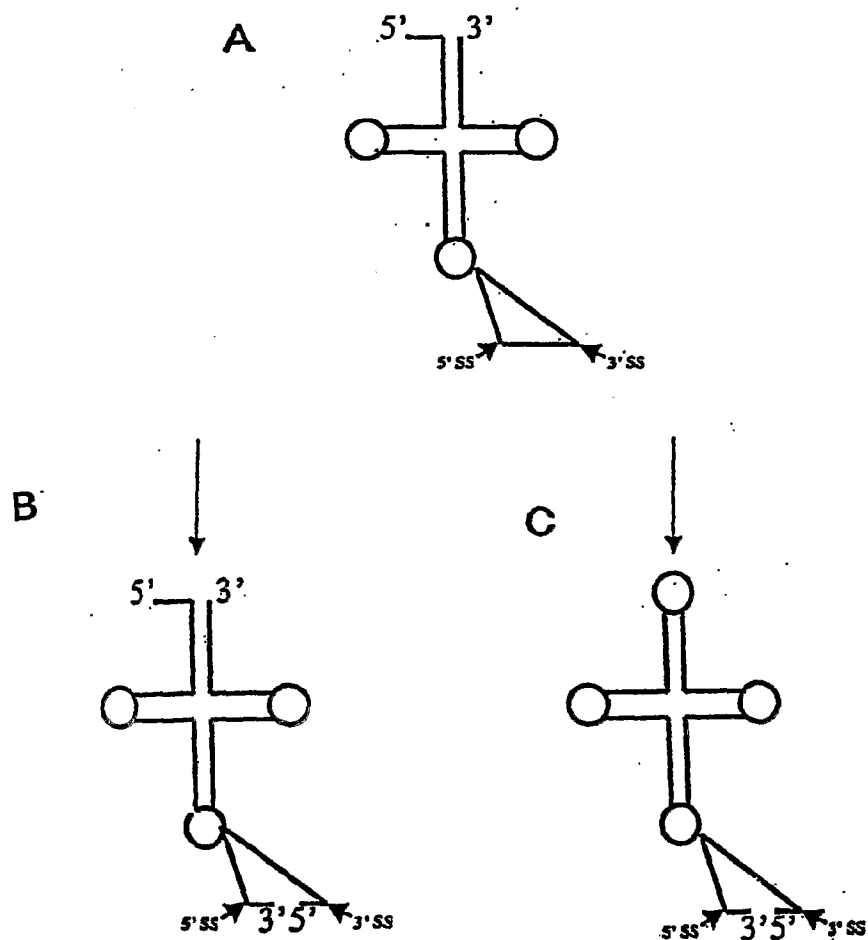


FIG. 1

# Removal of Introns from tRNA in Yeast

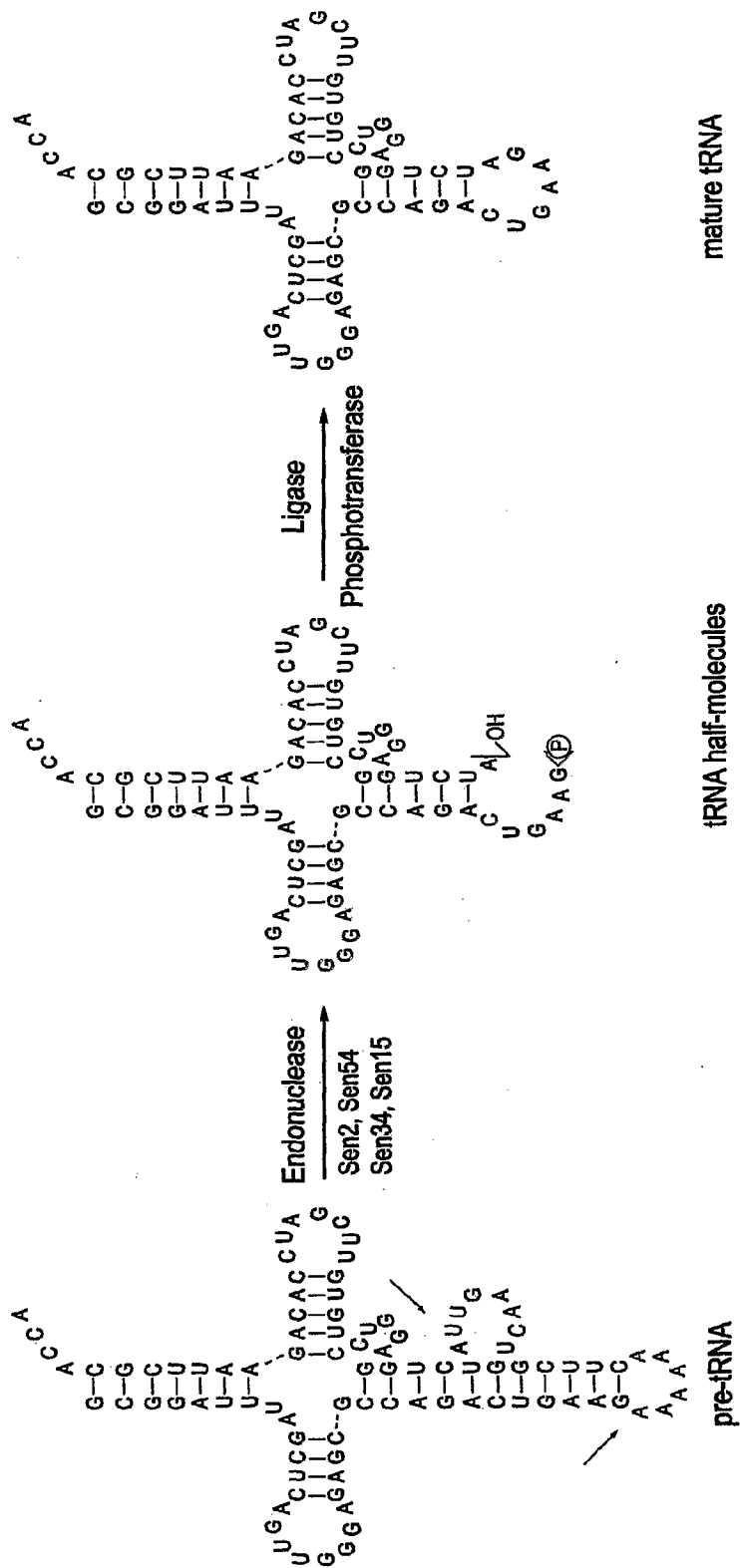


Fig. 2

# Yeast tRNA Splicing Endonuclease Holoenzyme

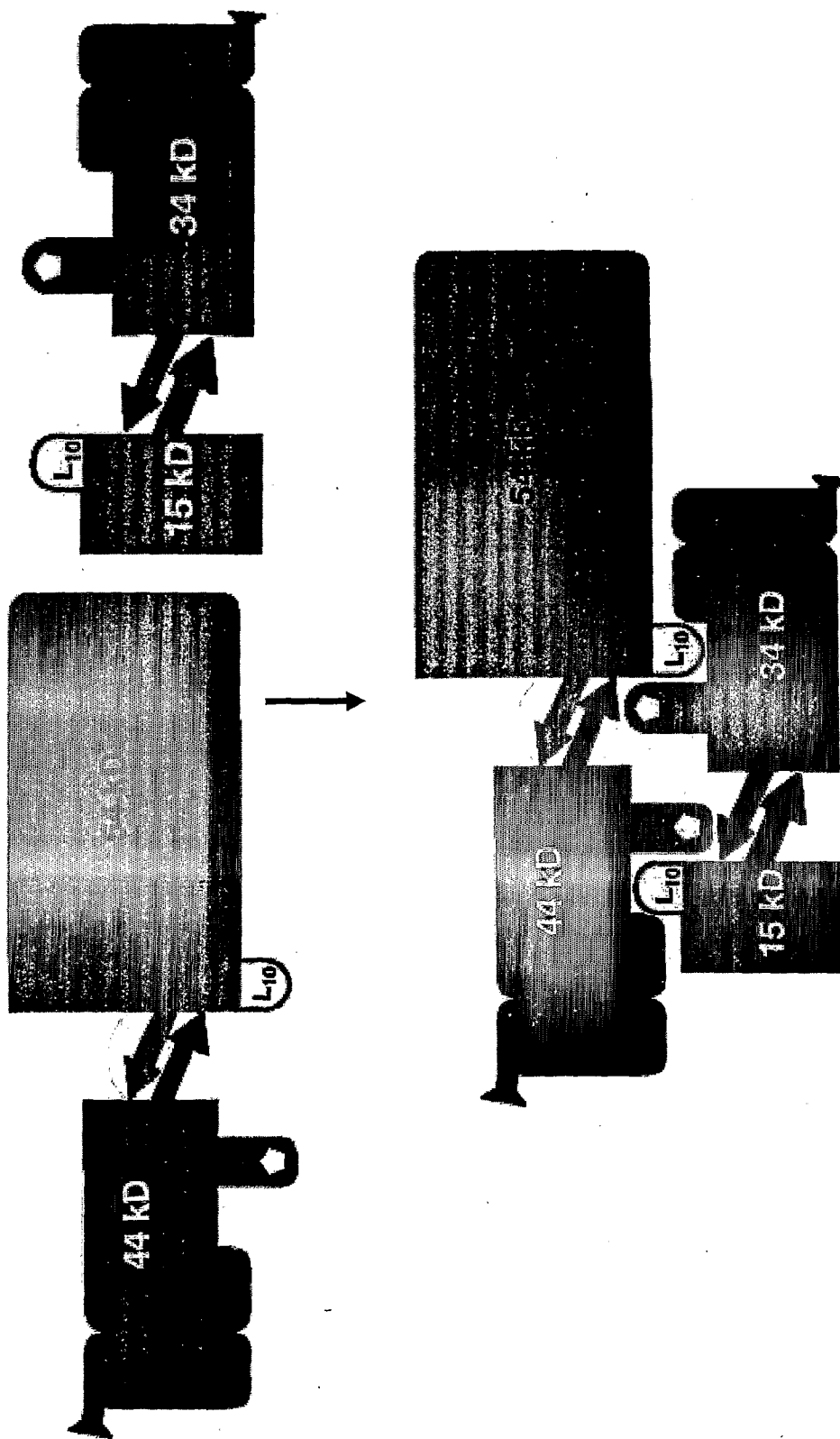


Fig. 3

# Model for Cleavage of tRNA by the Yeast tRNA Endonuclease

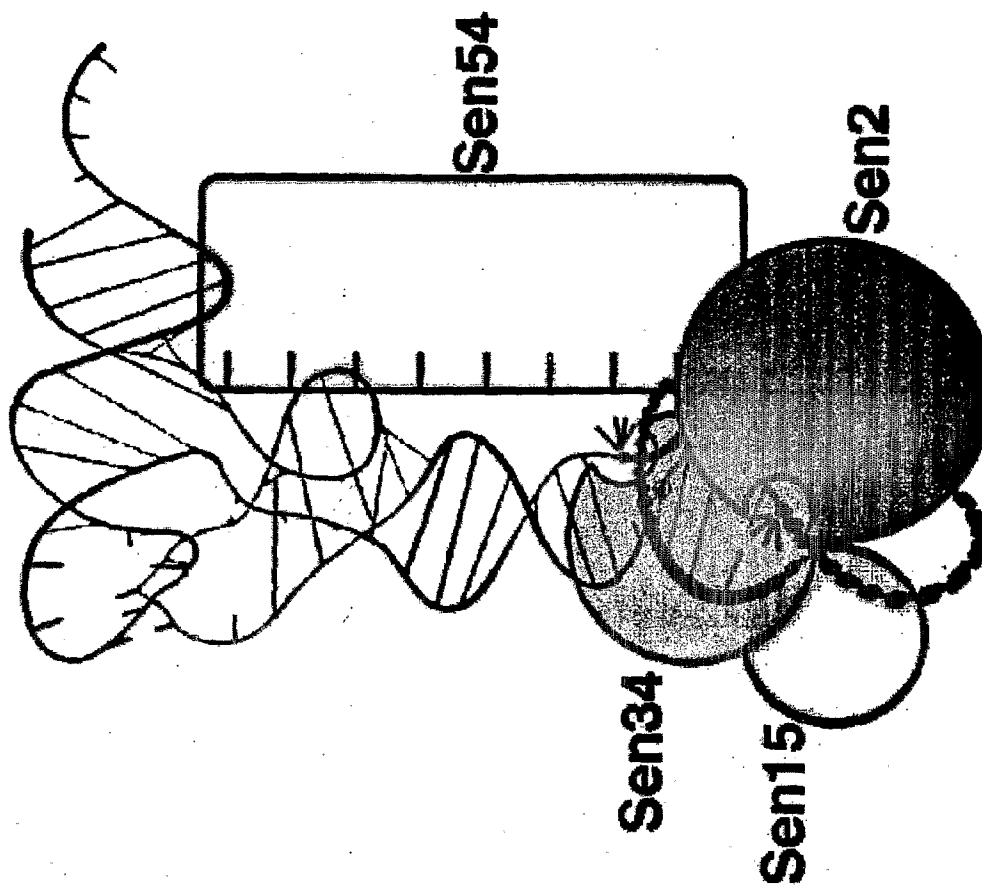


Fig. 4

# Sequence alignment of human and yeast tRNA splicing endonuclease Sen2 subunits

Hs Sen2p	1	MAEATTHAPK RRRVYETIE SPLPIFDQD HGPLKEKIP RAEMINHHVI	50
Hs Sen2 var.		MAEATTHAPK RRRVYETIE SPLPIFDQD HGPLKEKIP RAEMINHHVI	
Sc Sen2p		MAEATTHAPK RRRVYETIE SPLPIFDQD HGPLKEKIP RAEMINHHVI	
Hs Sen2p	51	YNAADIEDQL YKGNFEGKI LSMSRESFTI SDPLVAKWK DAKINMEI...	100
Hs Sen2 var.		YNAADIEDQL YKGNFEGKI LSMSRESFTI SDPLVAKWK DAKINMEI...	
Sc Sen2p		YNAADIEDQL YKGNFEGKI LSMSRESFTI SDPLVAKWK DAKINMEI...	
Hs Sen2p	101	...ITSKXYQ HAVENAAEIM HQQODESTV HILADYTKP LEHPFVKH	150
Hs Sen2 var.		...ITSKXYQ HAVENAAEIM HQQODESTV HILADYTKP LEHPFVKH	
Sc Sen2p		...ITSKXYQ HAVENAAEIM HQQODESTV HILADYTKP LEHPFVKH	
Hs Sen2p	151	EDAQVHDKIN SGWVSNMEST AGGERPSVYN GDSKSGGVG DERELACTQ	200
Hs Sen2 var.		EDAQVHDKIN SGWVSNMEST AGGERPSVYN GDSKSGGVG DERELACTQ	
Sc Sen2p		EDAQVHDKIN SGWVSNMEST AGGERPSVYN GDSKSGGVG DERELACTQ	
Hs Sen2p	201	ESGSGHEPTE SPEKSVR ED ASPLPHVCC KQALILQNG LHEDGESQHI	250
Hs Sen2 var.		ESGSGHEPTE SPEKSVR ED ASPLPHVCC KQALILQNG LHEDGESQHI	
Sc Sen2p		ESGSGHEPTE SPEKSVR ED ASPLPHVCC KQALILQNG LHEDGESQHI	
Hs Sen2p	251	GLIHGDSGSP DHEVIVVEEA ECAMSEREA FHELVQRNR LICRNPYRI	300
Hs Sen2 var.		GLIHGDSGSP DHEVIVVEEA ECAMSEREA FHELVQRNR LICRNPYRI	
Sc Sen2p		GLIHGDSGSP DHEVIVVEEA ECAMSEREA FHELVQRNR LICRNPYRI	
Hs Sen2p	301	FEYLQSLIE AFLVIVALEC LSTYKEKEI TIVKMKAPT VVQFTTITV	350
Hs Sen2 var.		FEYLQSLIE AFLVIVALEC LSTYKEKEI TIVKMKAPT VVQFTTITV	
Sc Sen2p		FEYLQSLIE AFLVIVALEC LSTYKEKEI TIVKMKAPT VVQFTTITV	
Hs Sen2p	351	MAHYFASKG WPKVGLKNG TDLATYKGP PFVHAASYVI IELVDHFGP	400
Hs Sen2 var.		MAHYFASKG WPKVGLKNG TDLATYKGP PFVHAASYVI IELVDHFGP	
Sc Sen2p		MAHYFASKG WPKVGLKNG TDLATYKGP PFVHAASYVI IELVDHFGP	
Hs Sen2p	401	SIRBPLSKWS LAALSRSVYN VKKELMCLYL IKESITMD...KEMESPE	450
Hs Sen2 var.		SIRBPLSKWS LAALSRSVYN VKKELMCLYL IKESITMD...KEMESPE	
Sc Sen2p		SIRBPLSKWS LAALSRSVYN VKKELMCLYL IKESITMD...KEMESPE	
Hs Sen2p	451	CMRLIKYQEV ILSHWASRE RSIQDQL	477
Hs Sen2 var.		CMRLIKYQEV ILSHWASRE RSIQDQL	
Sc Sen2p		CMRLIKYQEV ILSHWASRE RSIQDQL	

Fig. 5

# Human Homologs of the tRNA Endonuclease Active Site Subunits Sen2 and Sen34

A

ScSen2 1 ..... **NS**GEVYQKRYKYPPIHPVDD**LE**LTLLHPPLSOLYQAWRYKSTI**AL**MD**W**HDV**FI**GD**TT**HA..... **IT**WQDD**KQ**MLY**LM**MM**GF**FG**GI**GF**SR**SE**PT**..  
 SpSen2 1 ..... **NS**K..... **ME**GVY**KQ**AL**PT**SLAY**PL**PI**LI**LM**PL**MA**IP**PLAVRY..... **LR**MT**PR**QV**Q**W**Q**C**Q**LESD**LS**CV**W**TD**SA**L**K**K**PT**ST**ST**FG**KL**SR**SE**PT..  
 HsSen2 1 **NA**EA**VF**HAP**K**K**R**RY**VT**ET**NE**SP**PI**1..... **IF**G**Q**DE**PL**KE**FK**.. **ET**RA**EN**IN**NI**..... **N**W**LR**MA**ED**IT**Q**LY**CK**Y**FG**KL**IL**SR**SR**SE**FT**  
 ScSen2 88 ..... **WR**AK**TE**AR**CG**IND**TP**L**H**RG**GT**KS**N**T**ET**MT**TL**Q**W**Y**Q**RR**LR**LE**RR**K**RA**K**E**..... **RE**LE**EL**K**K**GG**EH**.....  
 SpSen2 84 ..... **ME**EN**IK**RS**SL**GL..... **LG**F**ED**I**VA**DE**VA**RE**RE**DE**K**Q**EA**Q**RA**Y**RE**NP**AR**ER**QL**LE**MG**K**P**1.....  
 HsSen2 73 **IS**DP**KL**VAK**Q**ED**UK**IN**PI**IT**SK**RY**Q**HS**VE**WA**AE**L**RR**Q**G**DE**SV**ET**ED**Y**TK**PE**TP**PK**RE**EA**Q**ED**EL**MS**ET**SN**ME**GT**AG**ER**PS**V**W**NG**D**SG**K**SG**GV**DP  
 ScSen2 160 ..... **DE**EN**IL**L**K**Q**ES**IR**K**KL..... **KQ**..... **TE**D**Y**GI**VA**Q**Q**DI**SE**SN**LR**DE**D**MD**AD**EN**GD**LL**P**  
 SpSen2 147 ..... **AS**LE**ED**AE**EL**PE**YL**DE**SI**K**D**SE**VS**EN**PI**YH.....  
 HsSen2 173 **RE**LG**CL**DE**SG**CH**PT**TES**FE**SV**ED**AS**PL**PH**V**CC**K**Q**D**AL**IL**Q**SG**HL**HE**D**G**SH**IG**LL**HP**GD**RG**PD**HE**Y**VL**VE**EA**E**CA**MS**ER**EA**AE**NE**EL**W**OR**ML**IC**RR**WP**Y**RI**  
 ScSen2 194 **LE**SE**EL**NP**EA**NP**IT**EA**IP**V**LD**ES**PA**CL**AG**K**FP**Q**AR**K**Q**D**H**.. **ST**RE**K**VI**VI**VS**RS**HC**VC**TS**ER**K**GC**D**EL**LY**RG**PP**FO**AE**R**..... **CV**MG**LD**HD**YS**K**Q**Y  
 SpSen2 190 **NP**TE**LD**IL**IL**K**RI**AN**IV**AN**SM**AI**HD**Y**SH**Q**SE**DE**PL**IED**M**.. **KE**TE**LA**Y**IV**ER**Q**Q**W**W**VE**NG**ES**W**DL**Y**K**K**GP**SE**AE**AT**LL**TP**CA**.. **CK**K**Q**Y**N**H**Q**H  
 HsSen2 273 **FE**Y**Q**LS**IE**EA**PL**VA**LG**CG**LS**Y**YE**KE**PT**IT**AV**L**OK**AF**IV**Q**PT**IT**TV**AY**HS**RG**W**PE**W**EL**K**Y**GL**IL**Y**RG**PP**Y**HA**SG**SV**IL**EL**VDD**H**FE**GS**TR**PI**LS  
 ScSen2 293 **M**.. **YS**SH**AR**W**EC**AK**TI**TE**MC**Y**ER**LI**SE**Q**AL**AL**AK**SM**NI**1..... **K**EN**SE**Q**CG**W**Y**K**RV**VE**GR**MD.....  
 SpSen2 285 **E**.. **WH**CL**OR**VI**AG**Y**K**SS**IL**CY**Y**.. **QC**PE**TE**Q**FN**K**IK**Q**IK**Q**AS**NE**WD**W**AE**ST**IR**Q**EL**RC**W**IL**RR**W**VP**SR**MD**.....  
 HsSen2 373 **IK**SL**AL**AE**SV**SV**VS**KE**ML**CY..... **IL**EP**ST**MD**KE**NE**S**TE**CM**ER**LI**K**Q**EV**IL**SE**MS**SE**RS**SD**Q**Q**QL**

B

ScSen34 1 ..... **MR**P..... **AV**ED**ED**EL**K**ARK..**ME**LC**Y**VS**PT**ER**DA**AD**OV**EL**SV**PR**IM**LE**DV**L**HL**AN**MA**..... **D**Y**ML**1..... **RO**EE**EL**ME**CI**TER  
 SpSen34 1 **ME**DE**K**PT**SY**VG**RR**FL**VD**Q**AV**EP**RR**AN**TH**IL**PL**VG**TH**Q**L**PR**Q**W**FL**EL**PL**SE**EA**Y**TE**K**GI**SV**WD**..... **PI**RV**VE**..... **KQ**..... **LE**ER..**IK**D  
 HsSen34 1 ..... **MT**VE**VA**NE**RS**L**W**GA**EA**VO**AL**ER**IG**GE**RT**W**EL**ER**GE**PR**OM**SR**UG**L**PL**MP**EE**AR**IL**AE**IT**AV**TS**AP**PD**SE**ES**L**ALT**SP**K**EQ**OE**SF**OE**GS**AL**AA  
 ScSen34 72 **CK**K..... **ISK**IVND**EL**AK**SE**FE**MR**K**T**.. **K**Q**Q**H..... **NA**K**IK**TE**GR**LN**K**Y**TA**ER**LR**MD**KE**SM..... **DQ**IES**SP**IT**DA**NT**SH**IL**RO**IES**DS**SL**SR**D  
 SpSen34 85 **D**YK..... **QC**KE..... **R**.. **Q**SL**AD**Q**UM**IT**ER**K**Q**KE**K**TE**IM**K**ER**..... **IL**.. **P**DP**PI**NT**Y**.. **DE**H..... **DS**FD**LS**Q**NP**VD**IV**TR**IA**ES..... **EM**MD**DP**KE  
 HsSen34 97 **EA**RE**TR**Q**EV**LE**K**IT**EG**QA**AK**Q**K**LE**QA**SE**SS**SO**EA**SG**AE**.. **DE**TS**IG**Q**AS**GE**DE**AG**PE**SS**Q**AG**PS**NG**VA**PP**RS**AL**LY**Q**AT**AR..**PE**PE**AR**PI**DU**.. **SV**  
 ScSen34 153 **DS**SL**ER**K**Q**Y..**Q**MG**K**Q**U**Y**PL**Y**AL**MD**Q**EV**LS**UG**GR**FE**K**FE**AG**GD**AR**FE**SE**L**IT**ODA**IV**VE**IE**..**P**UD**IS**IT**SE**AR**IG**TV**K**KL**MG**GV..... **AE**R  
 SpSen34 159 **E**.. **D**.. **VE**EL..... **DM**RV**MT**FE**SV**DT**ET**EL**MP**IR**FC**Q**W**AY**PD**AL**RE**SH**Y**LV..**NS**Y**K**Q**DD**UE..**IP**W**FL**IG**GR**IG**AV**K**KT**MD**LP**SD**NR**IN**Q**NE**K**  
 HsSen34 194 **Q**SK**D**..**MP**HA**GP**DE**EL**.. **ES**SV**ED**ME**RE**ET**L**SA**KE**TE**GD**EL**Y**FG**EP**ER**TH**AY**IA**GC..... **MA**ED**IT**LO**DA**AG**ET**SV**RE**K**IL**AL..... **C**SP**Q**PD**EK**..  
 ScSen34 251 **KE**K..... **TE**FF**ES**IM**AG**RG.....  
 SpSen34 246 **SE**EE**LL**AL**PL**PE**HE**.. **FE**TE**WA**PE**FS**.....  
 HsSen34 287 ..... **W**Y**T**.. **SL**Q**UA**SL**Q**UT**PE**T

Fig. 6

Fig. 7

# Protein alignment of Clp1 from different species

De Vries et al Embo Vol 19 No 21 pp 5895-5904  
2000

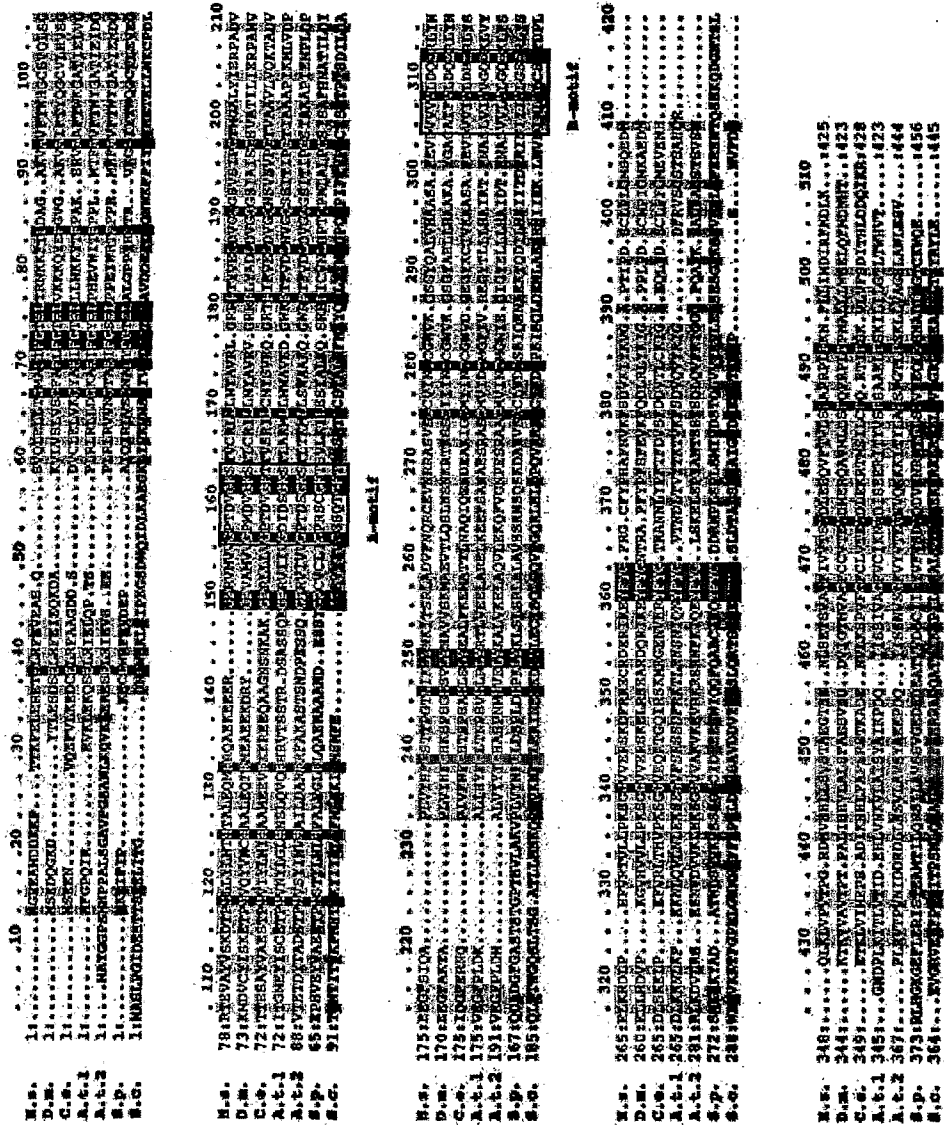


Fig. 8



# Components of the human endonuclease complexes

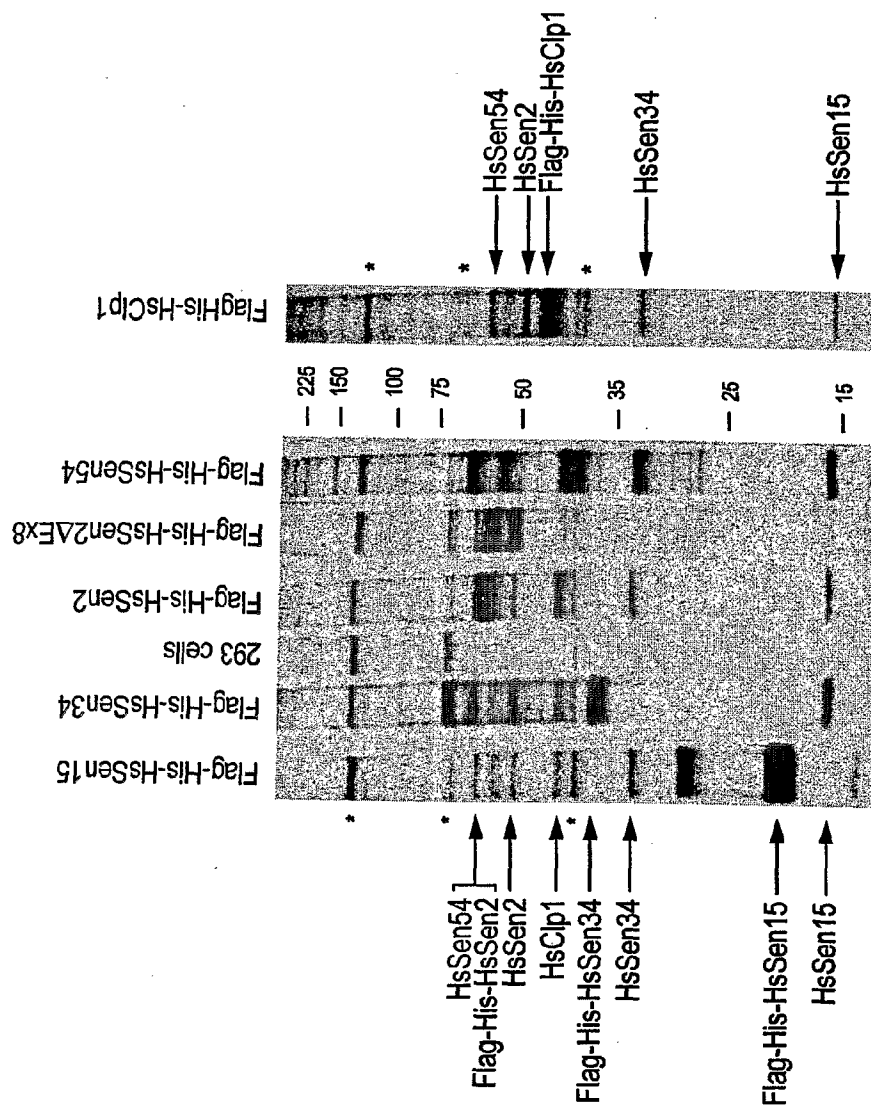


Fig. 9

# Proteins Co-purifying with Sen2, Sen34, Sen15 have pre-tRNA Splicing Endonuclease Activity

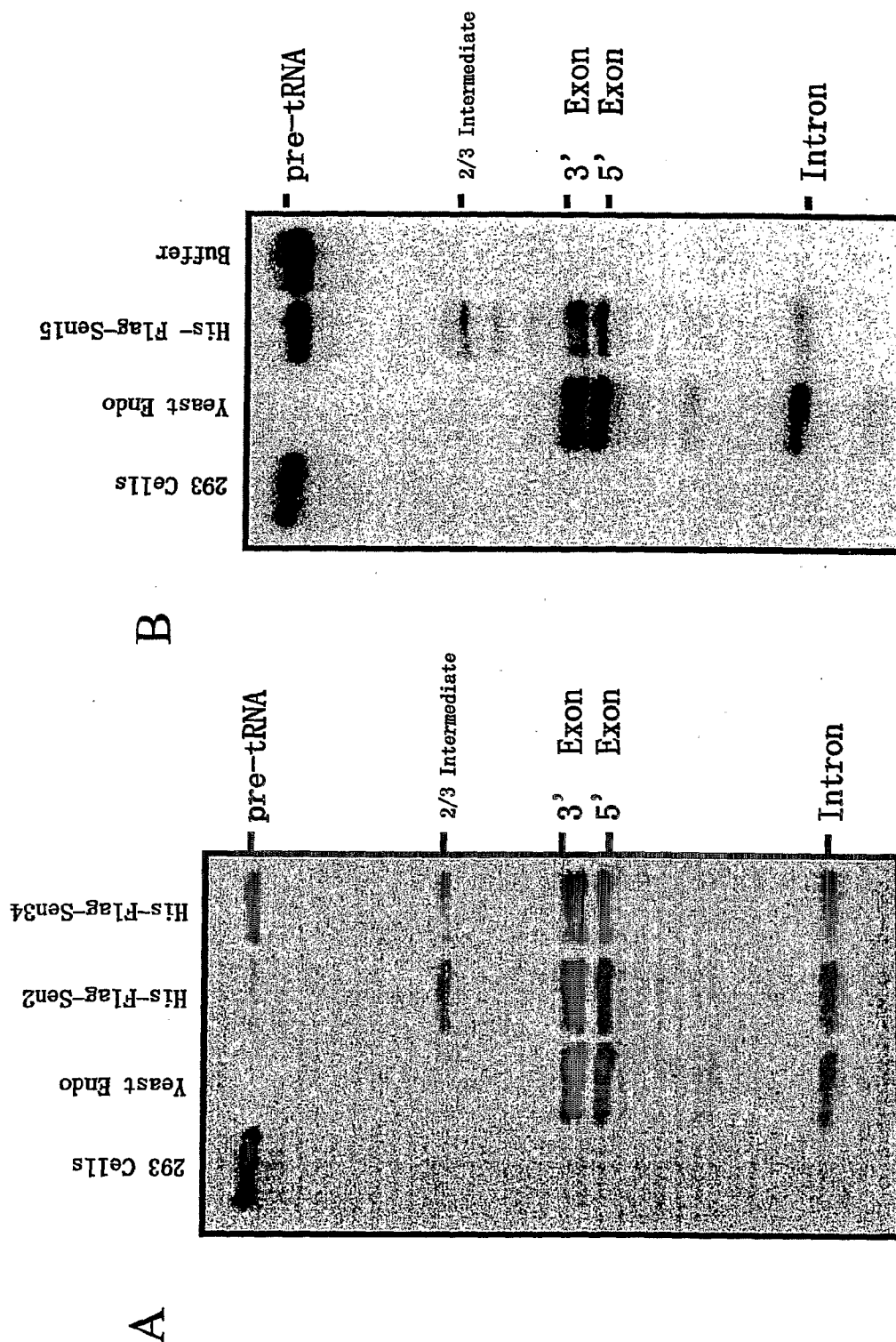


Fig. 10 A-B

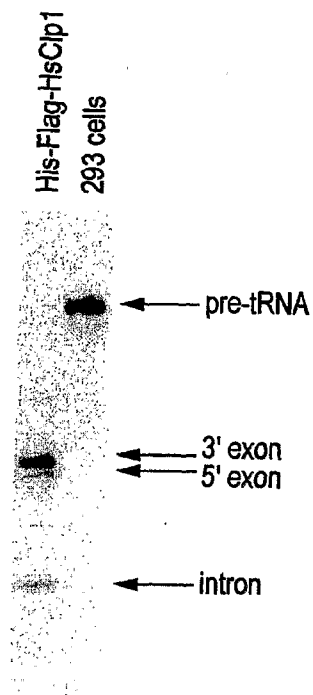


Fig. 10C

# Human tRNA Splicing Endonuclease Active Site Subunits are Localized in the Nucleus

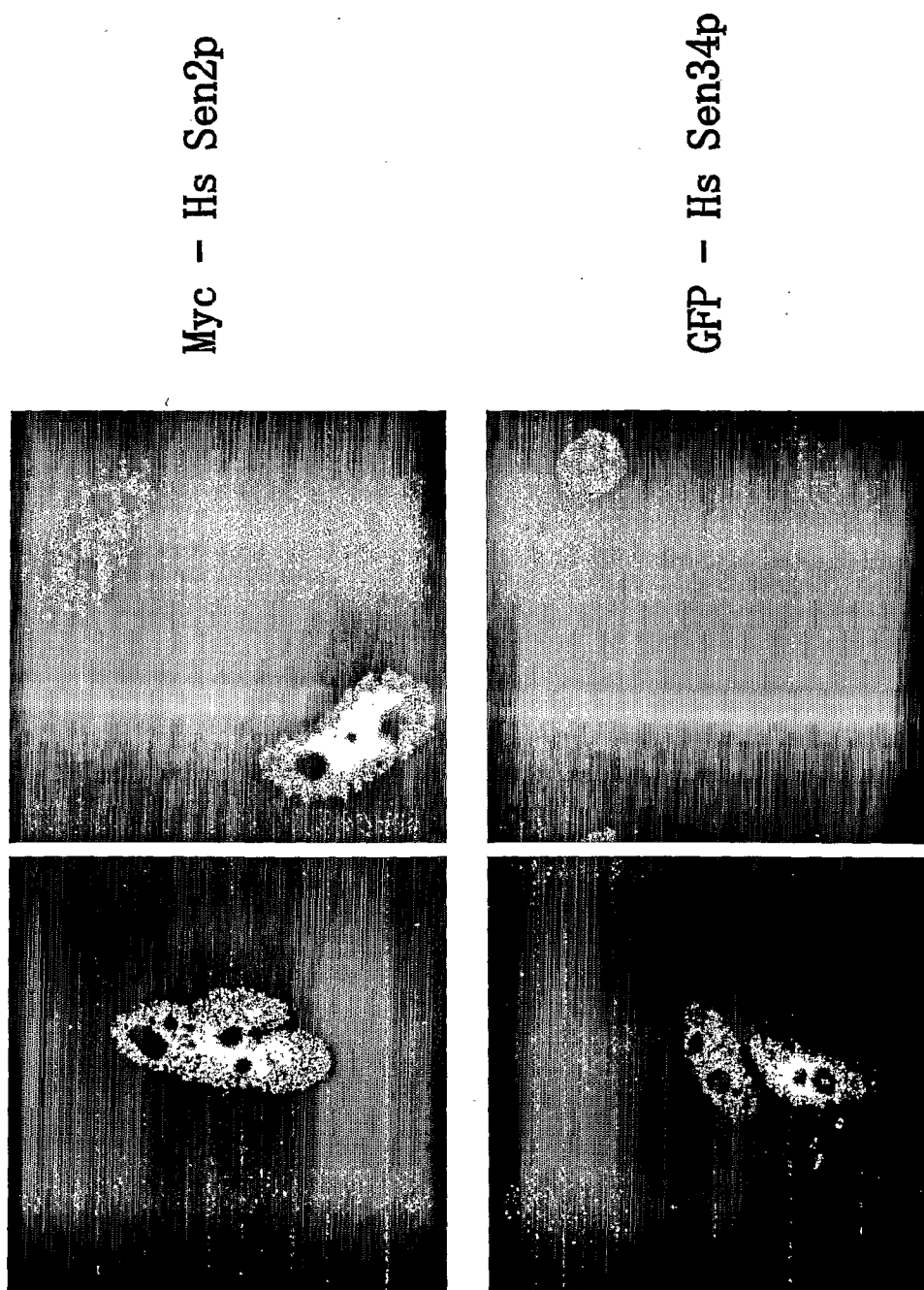


Fig. 11

# Active Site Subunit Sen2p is Alternatively Spliced

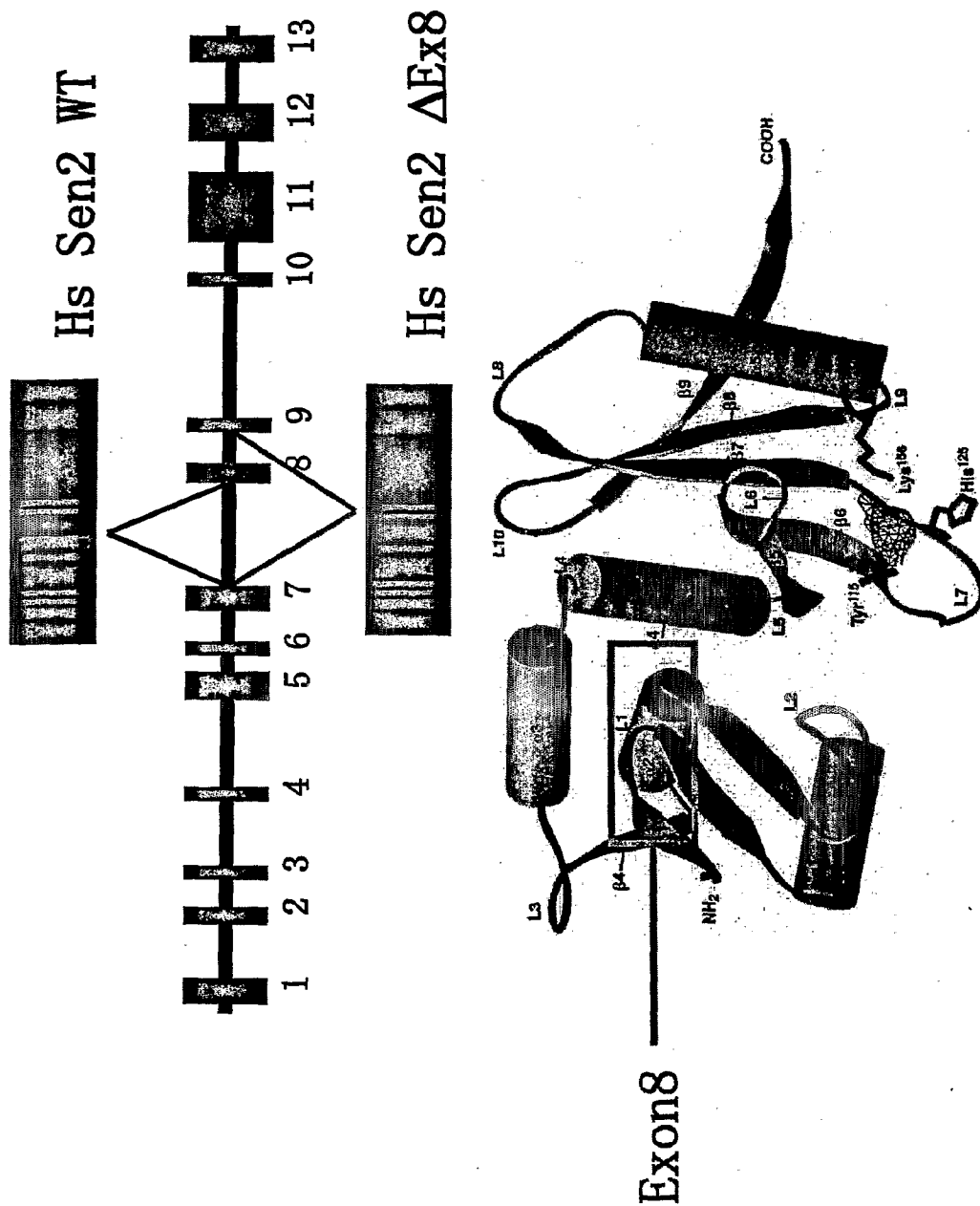


Fig. 12

# Alternatively Spliced Endonuclease is Expressed in all

## Tissues

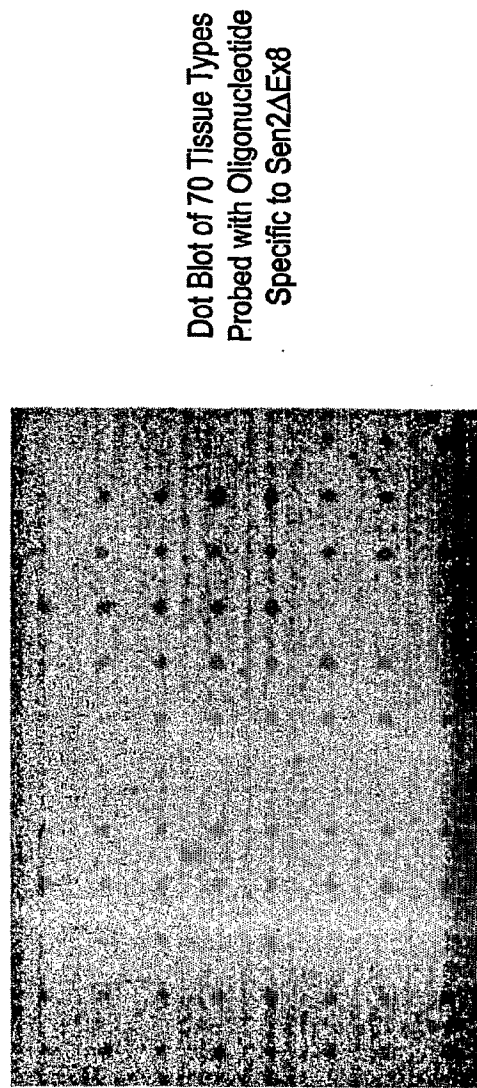
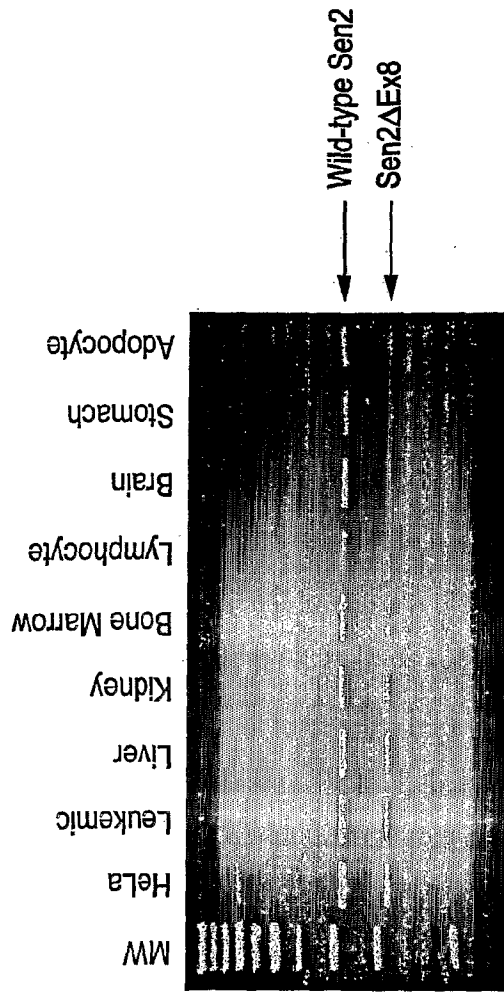


Fig. 13

Sen2ΔEx8 has decreased ability to bind Sen15 and Sen34

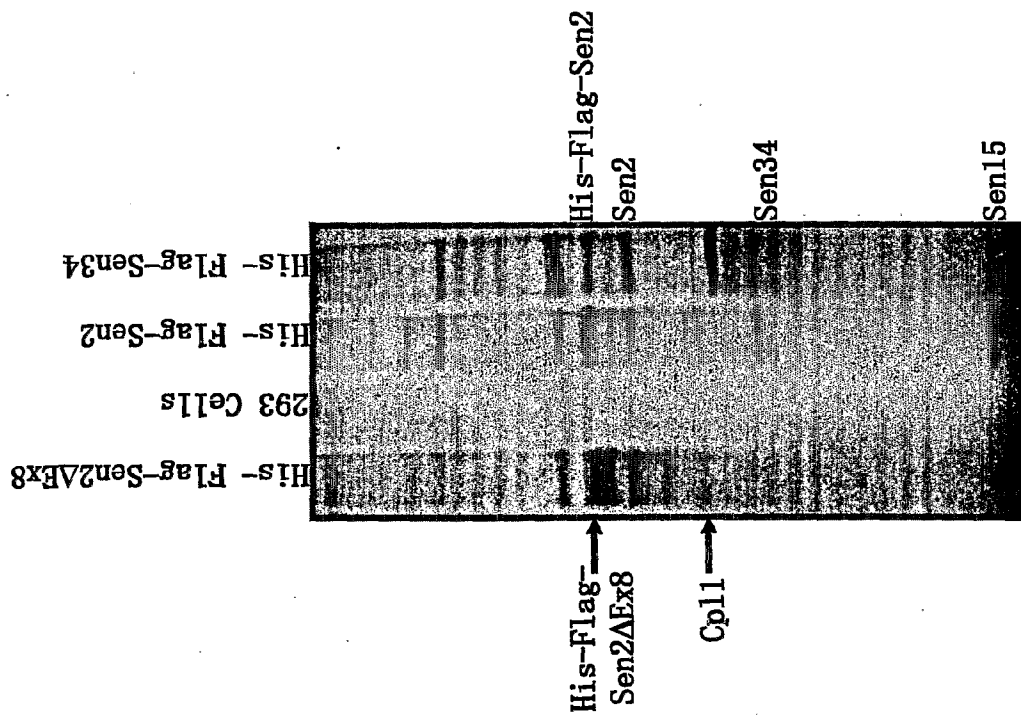


Fig. 14

# Endonuclease Containing Sen2ΔEx8 is Deficient in Cleavage of tRNA

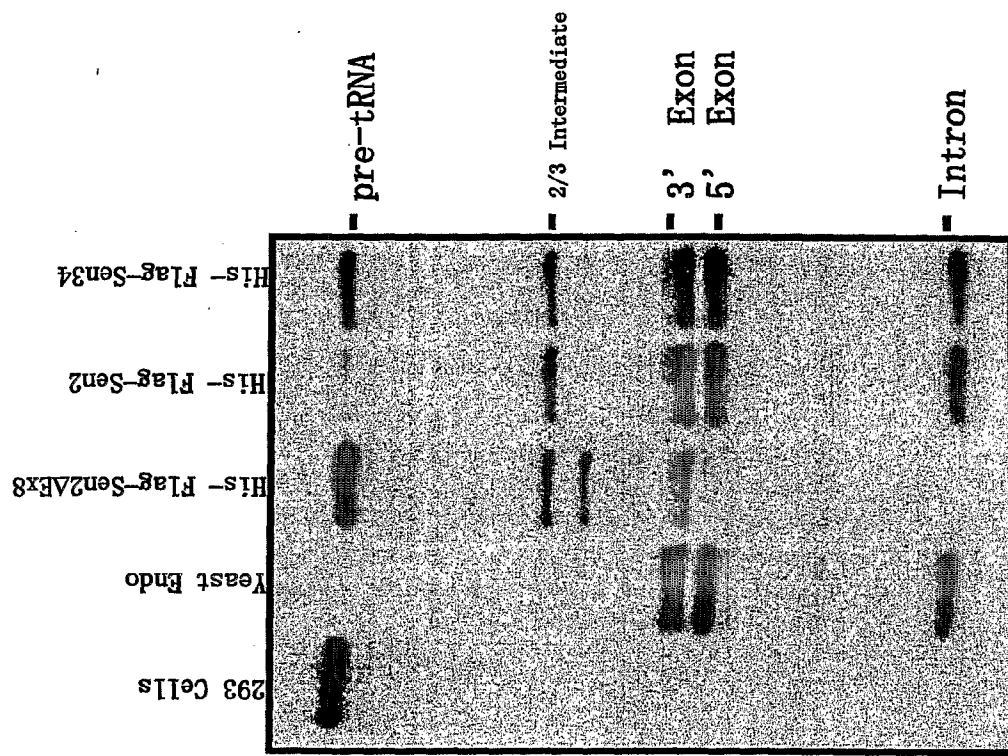
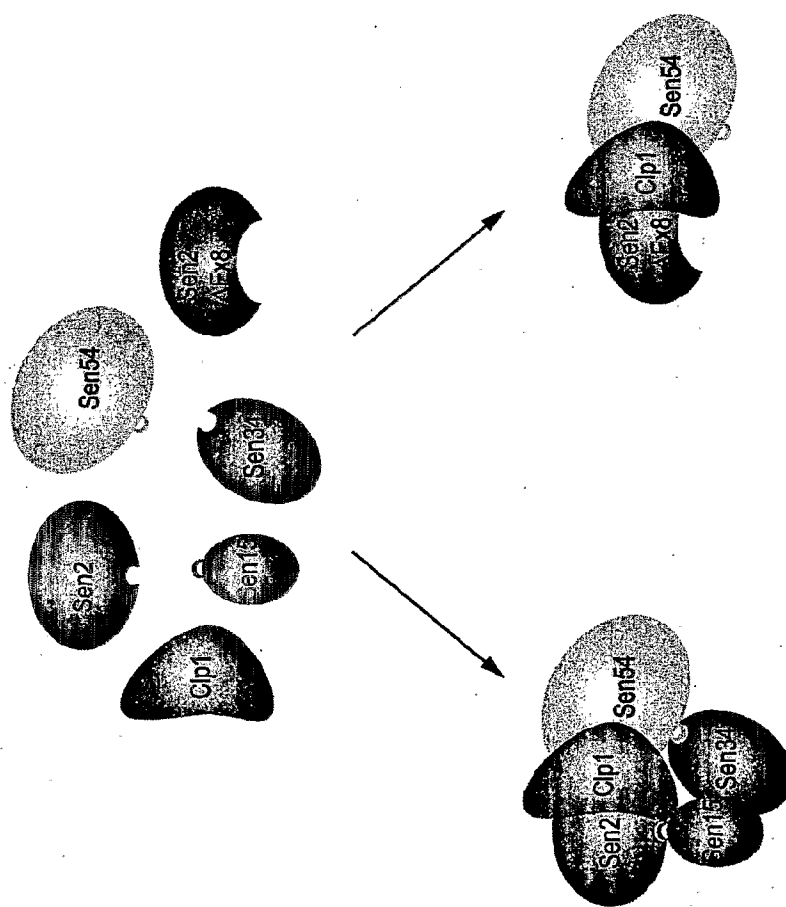


Fig. 15



# tRNA Splicing Endonuclease



tRNA splicing

Fig. 16

# tRNA Splicing Endonuclease Copurifies with 3' End Processing Factors

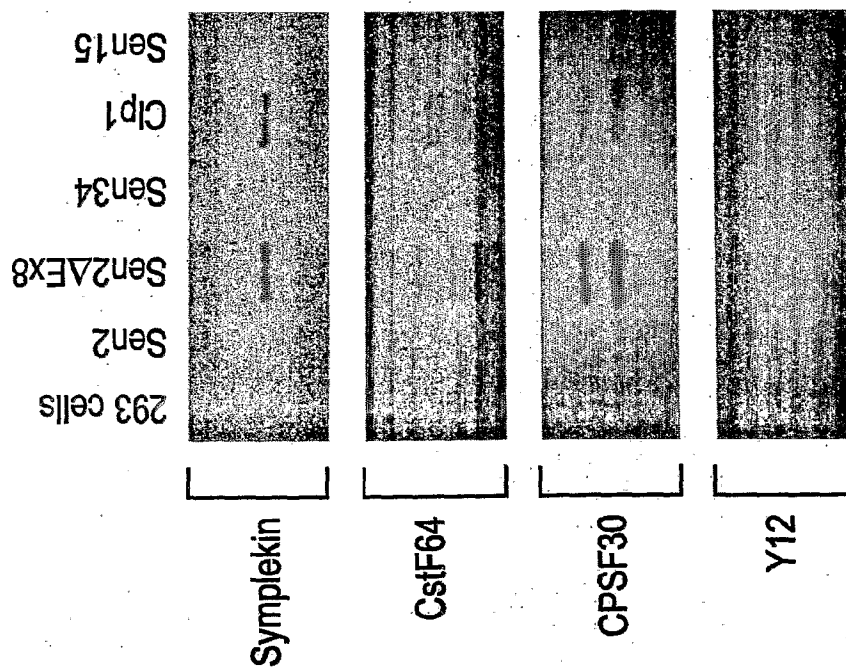


Fig. 17A

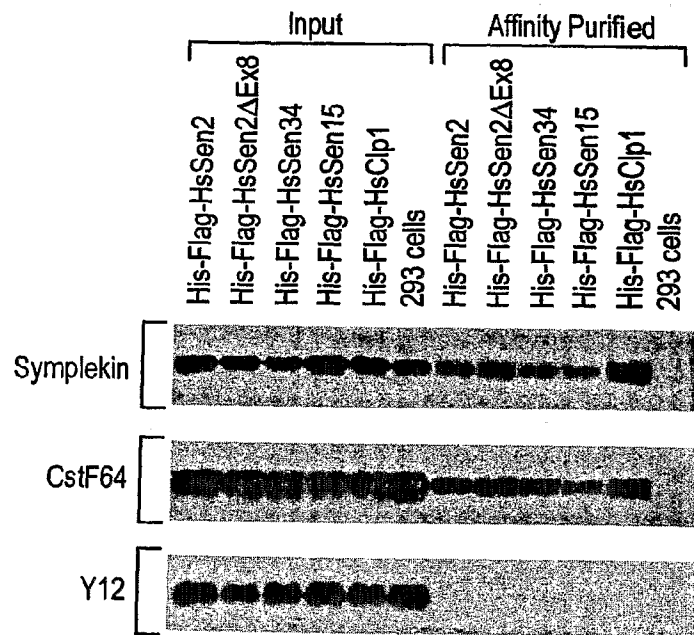
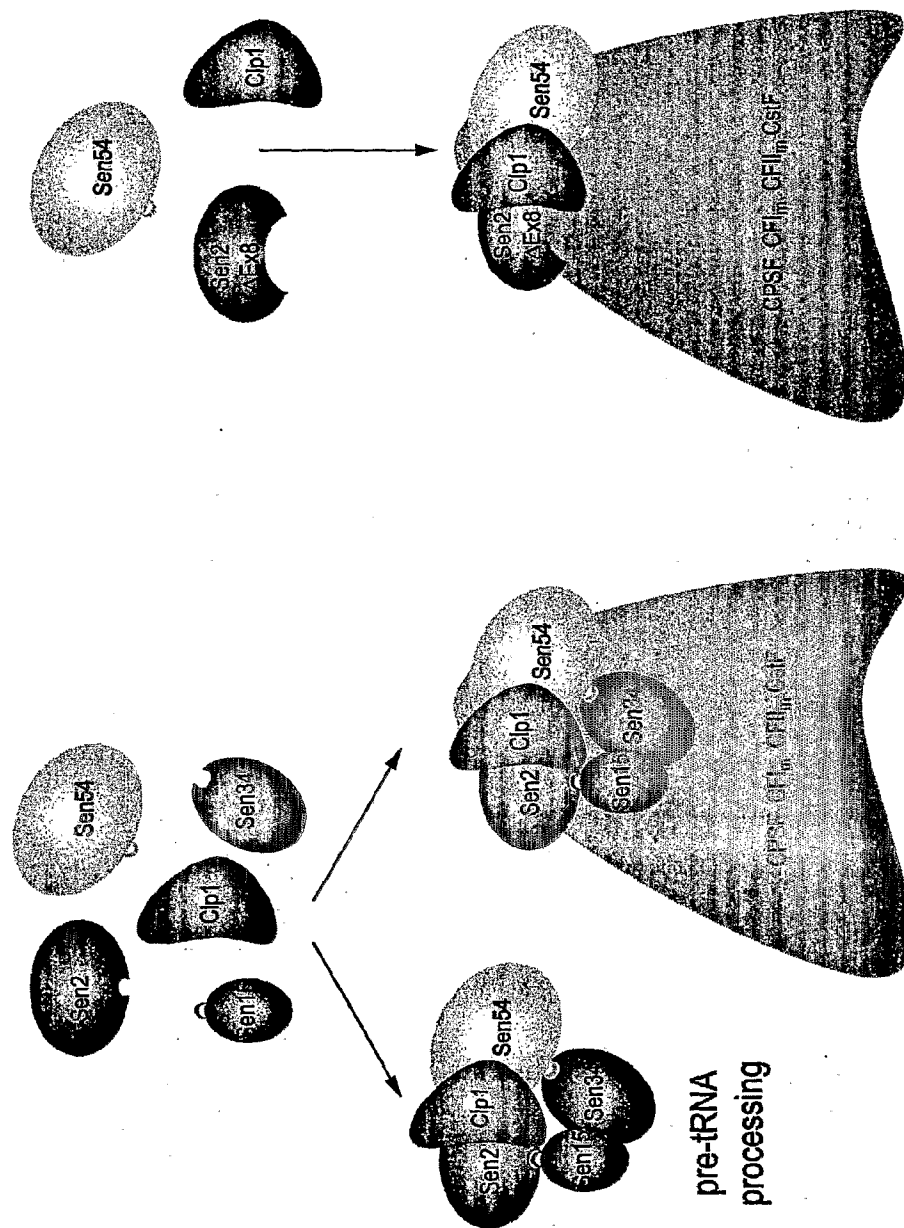


Fig. 17B

# Human Endonucleases process different types of RNAs



3' end mRNA processing

Fig. 18

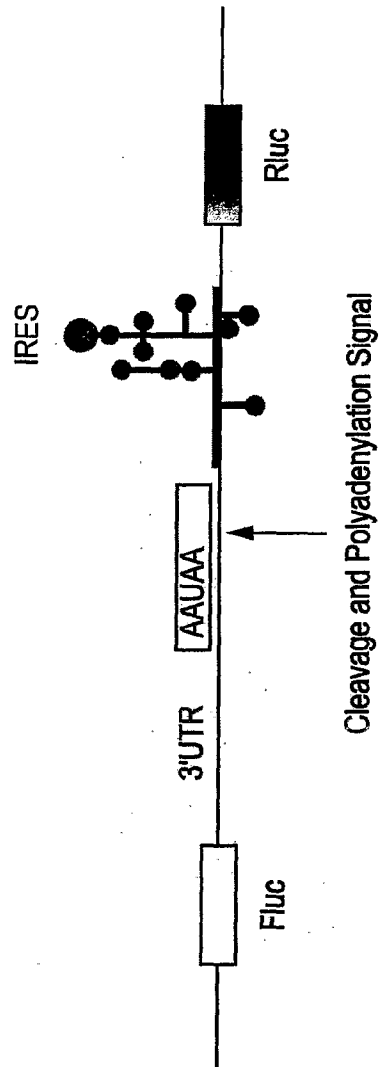


Fig. 19

## Sen2 Nucleic Acid:

```

1  gggcgaggaa agcgcgggcc tttccgagtt tgggtgtttg cagcgaaagg aaatctcgct
61  cttccgaaag tctccaggg cgagagagga aagggcctag gtactgtgct ggggtcgcac
121 agccggcgga gacagtgcgg ggacggggag ccagggttcc gagtgcgccc ggtcactgac
181 tctcccgccg tttcctcggt cgcctgcagc ccttggttct tggaaacgcc ggcgccttgt
241 tcagggctgg tggggctggg gcgcaagggt cagctgacaa tgcccagag gagccgcagc
301 ctctggtgga gttcggtcgg gtgtgggggt agtcaaggaa agaagcaaa ggaatacctc
361 ctctgaaaaa tggcagaagc agttttccat gccccaaaga ggaaaagaag agtgtatgag
421 acttacgagt ctccattgcc aatccctttt ggtcaggacc atggtcctct gaaagaattc
481 aagatattcc gtgctgaaat gattaacaac aatgtgattg tgaggaaatg ggaggacatt
541 gagcagctct atgggaaagg ttatttttga aaaggtattc tttcaagaag ccgtccaagc
601 ttcacaattt cagatcctaa actggttgct aaatggaaa atatgaagac aaacatgcct
661 atcatcacat caaagaggta tcagcatagt gttgagtggg cagcagagct gatgcgtaga
721 caggggcagg atgagagtac agtgcgcaga atcctcaagg attacacgaa accgcttgag
781 catcctcctg tgaaaaggaa tgaagaggct caagtgcattg acaagcttaa ctctggaatg
841 gtttccaaca tggaaggcac agcaggggga gagagacctt ctgtggtaaa cggggactct
901 ggaaagtcag gtggtgtggg tgatccccgt gagccattag gctgcctgca ggagggtctc
961 ggctgccacc caacaacaga gagctttgag aaaagcgtgc gagaggatgc ctcacctctg
1021 ccccatgtct gttgtctgca acaagatgct ctcatcctcc agcgtggcct tcatcatgaa
1081 gacggcagcc agcacatcgg cctcctgcat cctggggaca gagggcctga ccatgagtag
1141 gtgctggtcg aggaagcgga gtgtgccatg agcgagaggg aggcctgccc aaatgaggaa
1201 ttggtgcaaa gaaacagggt aatatgcaga agaaatccat ataggatctt tgagtatttg
1261 caactcagcc tagaagaggc ctttttcttg gtctatgctc tgggatgttt aagtatttac
1321 tatgagaagg agcctttaac gatagtgaag ctctggaaa ctttcactgt agttcagccc
1381 acgttcagaa ccacctacat ggcctaccat tactttcgaa ggaagggtgt ggtgcccaa
1441 gtgggactca agtacgggac agatttactg ctatatcgga aaggccctcc attttaccat
1501 gcaagttatt ctgtcattat cgagctagtt gatgaccatt ttgaaggctc tctccgcagg
1561 cctctcagtt ggaagtccct ggctgccttg agcagagttt ccgttaatgt ctctaaggaa
1621 cttatgctgt gctatttgat taaacctctc actatgactg acaaggaaat ggagtcacca
1681 gaatgtatga aaaggattaa agttcaggag gtgattctga gtcgatgggt ttcttcacga
1741 gagaggagt accaagacga tctttaacaa ttcaacctca aatttcta at ttcaccaaca
1801 actatttatt gagggctagg taaaaagttc tttttgttgt aatcgtccat taattcataa
1861 gtttttaaagg gcatgggtgct ccagcacca gaaaactatc agtgttttta aagataaatt
1921 acacaaggga ggagaaagat ccctgtgcta ggacaacaga ttctatactt gcgttggcct
1981 ctaactcccc catccagagc ctctgcctc tggcgtcagt tttttccctc atccactcac
2041 tggggagatt ggactagagg agtcctgaga ggacacttcc aacaagagac atttattctc
2101 tgattttacc tgaaaatggg agtagtttac atttatacag tacagtttat gaagcacttt
2161 catacgagg catctcttgt tacctacatc taagctgttc ccgaaagagt gttacagaac
2221 acaacagtat tgtacaatat tcgataagca tatcttcact gcacttgta taaaaatgag
2281 tgggtgaaata atgtttggag acataatgaa agcgattaac atttggcaaa atataataaa
2341 gcctttttgt aattggtgaa aaaaaaaaaa aaa

```

## Sen2 Amino Acid:

```

1  maeavfhapk rkrrvyetye splpipfgqd hgplkefkif raeminnnvi vrnaedieql
61  ygkgyfgkgi lsrsrpsfti sdplklvakwk dmktmnpit skryqhsview aaelmrrggq
121 destvrrilk dytkplehvp vkrneeaqvh dklngmvsn megtaggerp svvngdagks
181 ggvgdprepl gclqegsgch pttesfeksv redasplphv ccckqdalil qrglhhdggs
241 qhigllhpgd rgpdheyvlv eaeacamser eaapneelvq rnrlicrrnp yrifeylqls
301 leeafflvya lgclsiyyek epltiivklwk aftvvqptfr ttymayhyfr skgwpkvgl
361 kygtldllyr kgppfyhasy svielvdh fegslrrpls wkslaalsrv svnvskelm1
421 cylikpstmt dkemespecm krikvgevil srwssrers dqddl

```

Fig. 20

## Sen2deltaEx8 Nucleic Acid:

```

atggcagaag cagttttcca tgccccaag aggaaaagaa gagtgatga gacttacgag      60
tctccattgc caatcccttt tggtcaggac catggtcctc tgaaagaatt caagatattc      120
cgtgctgaaa tgattaacaa caatgtgatt gtgaggaatg cggaggacat tgagcagctc      180
tatgggaaaag gttatttttg aaaagggtatt ctttcaagaa gccgtccaag cttcacaatt      240
tcagatccta aactgggtgc taaatggaaa gatatgaaga caaacatgcc tatcatcaca      300
tcaaaagaggt atcagcatag tgttgagtg gacgcagagc tgatgcgtag acaggggcag      360
gatgagagta cagtgcgcag aatcctcaag gattacacga aaccgcttga gcatcctcct      420
gtgaaaagga atgaagaggc tcaagtgcac gacaagctta actctggaat ggtttccaac      480
atggaaggca cagcaggggg agagagacct tctgtggtaa acggggactc tggaaagtca      540
ggtggtgtgg gtgatccccg tgagccatta ggctgcctgc aggagggtc tggctgccac      600
ccaacaacag agagctttga gaaaagcgtg cgagaggatg cctcacctct gcccatgtc      660
tggtgtgtca aacaagatgc tctcatcctc cagcgtggcc ttcacatga agacggcagc      720
cagcacatcg gctcctgca tcctggggac agagggcctg accatgagta cgtgctggtc      780
gaggaagcgg agtggtccat gagcgagagg gaggtgcgcc caaatgagga attggtgcaa      840
agaaacaggt taatatgcag aagaaatcca tataggatct ttgagtattt gcaactcagc      900
ctagaagagg agcctttaac gatagtgaag ctctggaaag ctttcaactgt agttcagccc      960
acgttcagaa ccacctacat ggctaccat tactttcgaa gcaagggtg ggtgcccaaa      1020
gtgggactca agtacgggac agatttactg ctatatcgga aaggccctcc attttaccat      1080
gcaagttatt ctgtcattat cgagctagtt gatgaccatt ttgaaggtc tctccgcagg      1140
cctctcagtt ggaagtcctt ggctgccttg agcagagttt ccgttaatgt ctctaaggaa      1200
cttatgtctg gctatttgat taaacctct actatgactg acaaggaaat ggagtcacca      1260
gaatgtatga aaaggattaa agttcaggag gtgattctga gtcgatgggt ttcttcacga      1320
gagaggagtg accaagacga tctttaa      1347

```

## Sen2deltaEx8 Amino Acid:

```

1 maeavfhapk rkrrvyetye splpipfgqd hgplkefkif raeminnnvi vrnaedieql
61 ykgyfgkgi lsrsrpsfti sdpklvakwk dmktmmpiit skryqhsview aaelmrqgg
121 destvrrilk dytkplehvp vkrneeaqvh dklnsgmvsen megtaggerp svvngdsgks
181 ggvgdprepl gclqegsgch pttesfeksv redaspplhv ccckqdalil qrglhhdgs
241 qhigllhpgd rgpdheyvlv eaeacamser eaapneelvq rnrlcrrnp yrifeyqls
301 lee***** epltivklwk aftvvqptfr ttymayhyfr skgwvpkvgl
361 kygtldllyr kgppfyhasy svielvdh fegslrrpls wkslaalsrv svnvskelml
421 cylipstmt dkemespecm krikvqevil srwvssrers dqddl

```

\*Denotes deleted amino acid between Sen2deltaEx8 and Sen2

Fig. 21

## Sen15 Nucleic Acid:

```

1 agcgtggggt gcgggtcgtg gtgcaccacg ggagcgccgc accggccggc atggaggagc
61 gcggcgattc cgagccgacc ccgggctgca gcggcctggg tccgggcggt gttcgcggtc
121 ttggcgacgg cgggtggagct ccttcgtggg cccctgagga cgcttgagtg ggcactcacc
181 ctaagtatct agaaatgatg gaattagata taggagatgc cacccaagtt tatgtagcgt
241 tcttggttta cctggacctc atggaaagca aaagctggca tgaagtaaac tgtgtaggat
301 taccagaact ccagctcatc tgccttggtg gtactgagat agaaggggag gggttacaga
361 ctgtggtgce taccctcatc actgcttccc tcagccataa caggataaag gagatcttga
421 aggcattctc aaagttgcaa ggtgatccag atttgccgat gtcttttact ttggccatag
481 tggagtctga ttctacaata gtctattata aacttactga tggatttatg ctgccagacc
541 ctcagaatat ttctcttaga agatgacatc catgtttcct gatgcttggt ttattcatac
601 aagattggat ttgagacca tcagactgct tcatctttta tctcagaaat aggggtgacg
661 tacatagtga ggggtgactt cccatttcca taaggttttc attctgaaga gtaaaacttc
721 cccaggtaga agactttctc ctcttataaa aatatagggg gatttcttta aaactttggt
781 atctagagac agtttaatta cagtatatata caggtttatg cctaggatgt attcagatgg
841 gtgggacctg tgtgctgctt ttgtcatccc acaactcaag ttgtctcttt gttcttggct
901 gccactgcca gctcattggt gagactgcca tttctttctc ttactcagct ctccccagtg
961 ccttttgggc actgcagcta ccgtagaatg gcattttata tgtacctgtg caccacttcc
1021 tgtttacttt ttctcttcca gtaaaaagta aaagatttct ttcaattggg ctctccattg
1081 cagttactgt tatttctctt ttttggttaa ctttaaatca aaactcaaaa tatgttctac
1141 cagagtgtgt cttaagtaac ttacgtgtct taagtaacag ggaccagaga catgttacct
1201 acaagagttc tgggctatcc ttttcattct tatcacatat catagcttga atattacaac
1261 agtgtgggag agaatacaac gtaaaaatgt cttcattaat tagaccagct tattccactt
1321 ttgttaaatgt ctctcaaat gtacaaaagta taaaaaatta tatgcacaaa gatgttccaa
1381 gtgacattac ttttagtagc ccaaattata aaccacttta aagtttgggg taaagattgg
1441 caaacttttt ctataaaggg ccagaaagta actattttag gtttttaaac ctactgtctc
1501 tgtcataact tgtcaacact gctgtatgaa gcacaaaagc agccatagac aatacataaa
1561 caatacgggc gtggctttgt tccagtaaaa ctttggttac aaatgtgggt ccatagtttg
1621 tcattccctg gtctaggaaa tagtcaataa acagatatat acaaatgata cataatgtac
1681 ttattaaaaa ttagtaatga atattattaa aaacatgaaa atattacctt aagtaaaaat
1741 tgcaagacgg aaaagtgtat aagtgggtgt aatcatggct gaaataacag accaagcata
1801 tgataaaaag ataacaaagt aaatcaaatt actaactggg tatagtggga taggaggcag
1861 aaaatggatg actttgtctt ttctcaatgt ttttatttgt attttataat aaaaatgttt
1921 taaaattaaa aaaaaaaaaa aaa

```

## Sen15 Amino Acid:

```

1 meergdsept pgcsglpgg vrgfgdggga pswapedawm gthpkylemm eldigdatqv
61 yvaflyldl meskswehvn cvglpelqli clvgteiege glqtvvptpi taslshnrir
121 eilkasrkli gdpdlpmsft laivesdsti vvykltdgfm lpdpgnislr r

```

Fig. 22



## Sen34 Nucleic Acid:

```

1  cacctcgact gcgaattact gtttatgagg tgactcgctg gttctatcgg tggacagtgg
61  gacattctga agggaggcaa ggaggcggac tgagcgctcc caattgggga ggatgctggg
121 ggtggagggt gcgaacggcc gctccctggt gtggggagcc gaggcggtgc aggccctccg
181 ggagcgctg ggtgtggggg gccgcacggt aggcgccctg ccccgcgggc cccgccagaa
241 ctgcgcctg ggccctcccgc tgctgctgat gccgaagag gcgcggctct tggccgagat
301 cggcgccgtg actctgggtca gcgccccgcg tccagactct cggcaccaca gcctggccct
361 gacatccttc aagcgccagc aagaggagag cttccaggag cagagcgctt tggcagctga
421 ggcccgagg agccgtcgtc aggaggtcct ggagaagatt acggagggcc aggctgctaa
481 gaagcagaaa ctagaacagg cttcaggggc cagctcaagc caggaggccg gctcgagcca
541 ggctgccaaa gaggatgaga ccagtgatgg ccaggcttcg ggagagcagg aggaagctgg
601 cccctcgtct tccaagcag gacctcaaa tggggtagcc ccttgccca gatctgctct
661 ccttgctccag ctggccactg ccaggcctcg accggtcaag gccaggcccc tggactggcg
721 tgtccagtct aaagactggc cccacgccgg ccgccctgcc cagcagctgc gctacagtat
781 ctacagagac ctgtgggagc gaggcttctt cctcagtgcg gctggcaagt tcggaggtga
841 cttcctggtc tatcctggtg accccctccg cttccacgcc cattatatcg ctcagtgtg
901 ggcccttgag gacacctccc actccaagac ctggttgctg ctggcgccct tgggaaccagc
961 gtcagaaaaga cctgctcct ctgttctccg cagcctgatg gtaagggtgg ctacacctcc
1021 ctgcaatggg ccagcctgca gtgaactcca gagacctagg ggatgtggct gtgtcggcag
1081 caagagcctt tctggatggt cccagctct tctctgggag tctagaacat cctcctacct
1141 ttctccgcgg ttagtttttg attccaggtt ttcgaacact acatcttttt tatgttcttc
1201 cttgtttcaa agcacttatt ggctgtgttt ttgtagttac ctattttcac actgtgagct
1261 tcccgagaat ggggcctggg tttgattcat ctgttttcta cagggtttta gtctcaggag
1321 gtctcaataa acttggtata taaatgttaa aaaaaaaaaa aaaa

```

## Sen34 Amino Acid:

```

1  mlvvevangr slvwgaeavq alrerlvgvg rtvgalprgp rqnslrlglpl llmpeearll
61  aeigavtlvs aprpdsrhhs laltsfkrqq eesfgeqsal aaearetrrq evlekitegq
121 aakkqkleqa sgasssqeag ssqaakedet sdggasgeqe eagpsssqag psngvaplr
181 sallvqlata rprpvkarpl dwrvqskdwp hagrpahelr ysiyrdlwer gfflsaagkf
241 ggdflypgd plrfhahyia qcwapedtsh sktwlllgall epaserpcss vlrslmvrws
301 tppcngpacs elqrprgcgc vgskslsgcs pallwesrts sylsprlvfd srfstnttsfl
361 cslfsgstyw lcfcsylfsh celpengawv

```

Fig. 23

## Sen54 Nucleic Acid:

```

1  gcggcgcgcg  cagcggcgagg  cggcgggcggg  atggagcccg  agccccgagcc  cgcggccgtg
61  gaggttcccc  cggggcgcggt  gctcagcgcc  cgggagctct  tcgcccgcgcg  ctgcgggtcg
121  cagaagctgc  cccagcgctc  gcatggcccc  aaggactttc  tgcccgcagcg  ctgcgcagct
181  caggccgagc  ggctgcgcgc  gtgcccggaa  gagctctggc  agctgctggc  agagcagcgc
241  gtggagcgcc  tgggcagctt  ggtggctgcc  gaggggaggg  cagaagaggg  cttcgtggag
301  ttgaagtctc  ccgcccggcaa  attctggcag  accatgggct  tctcagagca  ggccggcgag
361  cgccttcacc  cggagagggc  cttgtatctt  ctggagtgtg  gctccatcca  cctcttcacc
421  caagacctgc  cactgtctat  ccaggaagct  taccagctgc  tgctgaccga  ccacactgtg
481  accttctctg  agtaccaggt  cttcagccac  ctgaagaggt  tgggttatgt  gggtcgacga
541  ttccaaccaa  gctctgtctt  gtcccgtat  gagaggcagc  ttaacctgga  tgccagcgtg
601  gcacacttgg  aggatggaga  tggcaagaga  aagaggagca  gctccagccc  tcggtccatt
661  aataagaagg  ccaagggcct  ggacaactcc  ctgcaaccca  agagtctggc  agcctccagc
721  ccacctccct  gcagccagcc  cagccaatgc  ccagaggaga  aaccccagga  gtcaagcccc
781  atgaagggcc  cagggggccc  ctttcagctt  ctggggtccc  tgggccccag  ccctggcccg
841  gccagggagg  ggggtgggtg  cagctgggag  agtggcagag  ccgagaacgg  agtcacggga
901  gccggtaagc  ggcgctggaa  cttcgagcag  atctccttcc  ccaacatggc  ttcagacagc
961  cgccacaccc  ttctgcgcgc  cccagcccca  gagctgtctc  cggccaacgt  ggctggggcg
1021  gagacagacg  ctgagtcttg  gtgccagaag  ctgaaccagc  gcaaggagaa  gctctccagg
1081  cgggaacggg  agcaccacgc  ggaggccgcg  cagttccagg  aagatgtcaa  cgccgatccc
1141  gaggtgcagc  ggtgctccag  ctggcgggag  tacaaggagc  tgctgcagcg  gcggcaggtg
1201  cagaggagcc  agcgcggggc  cctccacctg  tggggccagc  ccgtcaccac  gctgctgagt
1261  cctggccagg  ccagctcccc  agccgtggtc  cttcagcata  tctctgtgct  gcagacaaca
1321  caccttcttg  atggaggtgc  ccggtctgtg  gagaagtctg  ggggcttggg  aatcatcttt
1381  gatgtttacc  aggccgacgc  tgtggccaca  ttccgaaaga  ataaccttgg  caaaccttat
1441  gcccgatgt  gcattagtgg  attgatgag  cctgtcccag  acctctgcag  cctcaagcgg
1501  ttgtcttacc  agagtgggga  tgtccctctg  atctttgccc  tgggtggatca  tgggtgacatc
1561  tccttctaca  gcttcaggga  cttcacgttg  cccagagatg  tggggcactg  acctcacagc
1621  tctgcagagg  atggagcttg  ctccggggga  ccgggactgt  ctgttctcag  ggaccatctc
1681  ggctgcctcc  tgtaccaga  ctctaacctg  tagcttcaga  ggccagtctg  ggcttggcc
1741  ctgggtgtct  gatactcaca  gaggtaaaact  gtgacctctc  cccttccctg  ctgcttggca
1801  gtgacctctc  tggaaactcag  gactcgattt  taaggaccca  ggaggtgggg  cagaagagag
1861  gactgtgtgc  ctttaacgag  agggtgcctg  ctctgtgcta  taaagccaaa  gccattaaaa
1921  atagatttct  tt

```

## Sen54 Amino Acid:

```

1  mepepepaav  evpagrvlsa  relfaarsrs  qklpqrshgp  kdfldpgsaa  qaelrrrcr
61  elwqllaegr  verlgslvaa  ewrpeegfve  lkspagkfwq  tmgfseqgrq  rlhpeealyl
121  lecgsihlfh  qdlplsiqea  yqllltdhtv  tflqyqvfs  lklrgyvvr  fqpssvlspy
181  erqlnldasv  qhldgdgkr  krssssprsi  nkkakaldns  lqpkslaass  pppcsqpsqc
241  peekpqessp  mkgpggpfql  lglgspgpg  aregvgswe  sgraengvtg  agkrrwnfeq
301  isfpnmasds  rhtllrapap  ellpanvagr  etdaeswcqk  lnqrkeklsr  rerehhaaea
361  qfqedvnadp  evqrcsswre  ykellqrrqv  qrsqrraphl  wgqpvtplls  pgqasspavv
421  lqhisvlqtt  hlpdggarl  eksggleiif  dvygadavat  frknpngkpy  armcisgfde
481  pvpdlcslkr  lsyqsgdvpl  ifalvdhgd  sfysfrdftl  pqdvgh

```

Fig. 24

## hClp1 Nucleic Acid:

```

1 atgactgact tgtagctgga agaaatcacc ggattttttat tcttttatta aagaaaaaaa
61 atttgaaatg ccttccatgt gccagcact gtgtcagggtg ggagatgaca gcttggtgaa
121 acctctgtca ggctgtcttc ctccgcttcc tctatccctg ggtttccccc tgccataaaa
181 ggattttgtg cttcgtggct tgtccaggca agcaggccgt cgccgggacct agaccgagac
241 agtgagtcct tctttctccc gggcctccct tctgtttcct gggtgcagg ggagcaggaa
301 atctggggcg agattccgc cgccggacgg cactgccgaa gcctgggtccc tcgacctgtc
361 cctgcccagc gccggggcgc aaccgccacg cctcctcacc cctccctccg gctgcacgaa
421 taatgacaac agccgcccct cccacctttg gcgtcacggt caaaacaatc ctttgactac
481 aactcccaga aggccgagcg gcttagcgag tgcaccgcgt ctccggctgt ccggcaaaact
541 acacatccca aagggcagcg ccgaccgcgt gtcctttcac agcaaatgac ggaactgcgt
601 ttgtttccgg cgtgggtccg ggcaagaacc gctttagtct tgggtttaa atctgcacggg
661 aggaccttct gagtttacct gtgggtctcc tggctgcgca ggcacagcag ctacacagaa
721 gagatgggag aagaggctaa tgatgacaag aagccaacca ctaaatttga actagagcga
781 gaaacagAAC ttcgctttga ggtggaggca tctcagtcag ttcagttgga gttgttgact
841 ggcatggcag agatctttgg cacagagctg acccgaaaca agaaattcac ctttgatgct
901 ggtgccaaag tggctgtttt cacttgcat ggtgtgtctg tgcaactgag ccggccgact
961 gaggtggctt atgtctccaa ggacactcct atgttgcttt acctcaacac tcacacagcc
1021 ttggaacaga tccggaggca agcggaaaag gaagaagagc aggtgcccg ggaactgcta
1081 gtgggcccc ctgatgtggg caagtctaca gtgtgtcgcc ttctgtcaa ctacgcagt
1141 cgtttgggccc gccgtcccac ttatgtggag ctggatgtgg gccagggttc tgtgtccatc
1201 cctggatacca tgggggccc ctacatcgag cggcctgcag atgtcgaaga ggggttctct
1261 atccaggccc cctgggtgta tcattttggt tccaccactc ctggcactaa catcaagctt
1321 tataataaga ttacatctcg tttagcagat gtgttcaacc aaagggtgta ggtgaaccga
1381 agggcatctg tgagtggctg tgtcattaac acctgtggct ggggtcaagg ctctgggtac
1441 cagggtctgg tgcagtcagc ctacgctttt gaggtggatg tgggtgtgt tctggatcaa
1501 gaacgactgt acaatgaact gaaacgggac ctcccccact ttgtacgcac tgtgtgtctc
1561 cctaaatctg ggggtgtggg ggagcgctcc aaggacttcc ggccgggaatg tagggatgag
1621 cgtatccgtg agtattttta tggattccga gggtgtttct atccccatgc cttcaatgtc
1681 aaattttcag atgtgaaat ctacaaagtt ggggcaccca ccatcccaga ctctgttta
1741 cctttgggca tgtctcaaga ggataatcag ctcaagctag tacctgtcac tctgggcca
1801 gatattgtgc accacctact gagtgttagc actgcccagg gtacagagga gaacctgtcc
1861 gagacaagtg tagctggctt cattgtgggt accagtgtgg acctggagca tcagggtgtt
1921 actgttctgt ctccagcccc tcgcccactg cctaagaact tccttctcat catggatata
1981 cggttcatgg atctgaagta gagatcagca ggaagccttg ctgcctggga catagagata
2041 atctggccac ccctagagcg agatgggctg agataaaaga ctgttggggc cacctgacca
2101 gtaaacgtg gactagtaga aagttcatat tctacctcta aaacaggta gtgtaacct
2161 gactcttcta atcttgaacc aaaaggaaaa ccatgagact gtaattggtt tcttagacca
2221 cctaagatgc cactttgaat tctctaagac cctggagaat tgcatttctt tcaactgtct
2281 actatgtggt ttttaaaaaa tcaatgcttt atattccata tgtgttctt acccatttat
2341 catggatgaa agtgtgaatt agagggactc cttccaataa agttcaaaact gaaaaaaat
2401 cattttaata aatatttttg ccatatcata aaaaaaa

```

## hClp1 Amino Acid:

```

1 mgeeanddkk pttkfelere telrfeveas qsvqlelltg maeifgtelt rnkkftfdag
61 akvavftwhg csvqlsgrte vayvskdtpm llylnhtal eqmrrqaeke eergprvmvv
121 gptdvkstvc crlllnyavr lgrrrptyvel dvqggsvsip gtmgalyier padveegfsi
181 qaplvyhfgs ttpgtnikly nkitsrladv fnqrcevnrr asvsgcvint cgwvksgsyg
241 alvhaasafe vdvvvldge rlynelkrdl phfvrtvllp ksggvversk dfrrecrder
301 ireyfygfrg cfyphafnvk fsdvkiykv aptipdsclp lgmsqednql klvpvtpgrd
361 mvhhllsvst aegteenlse tsvagfivvt svdlehgvt vlsapaprplp knfillimdir
421 fmdlk

```

Fig. 25

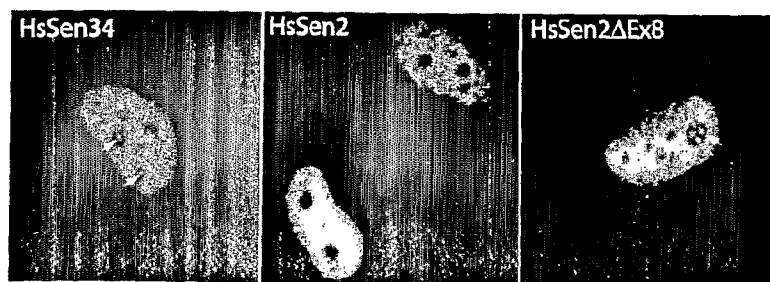


Fig. 26

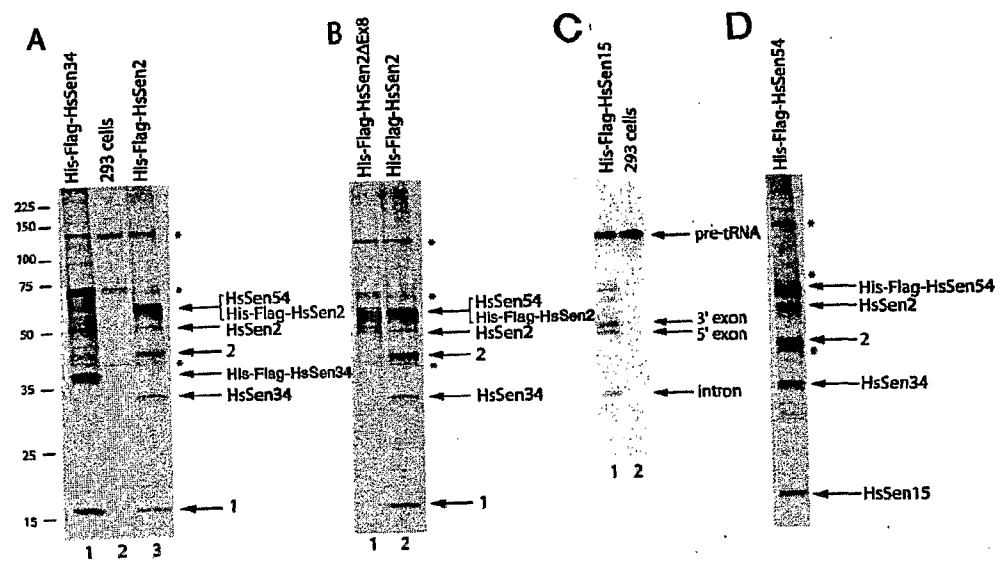


Fig. 27

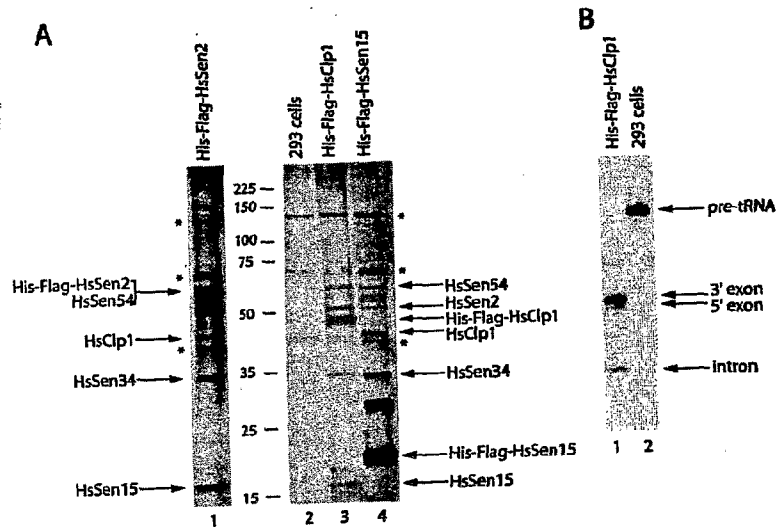


Fig. 28

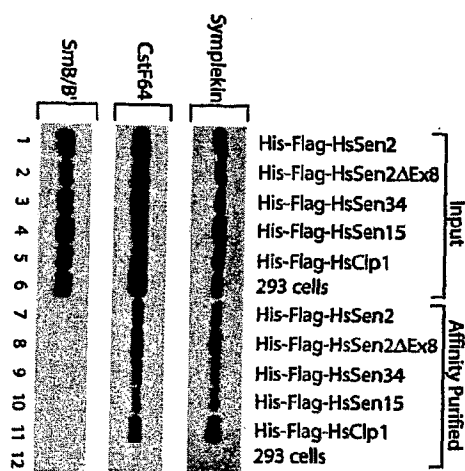


Fig. 29

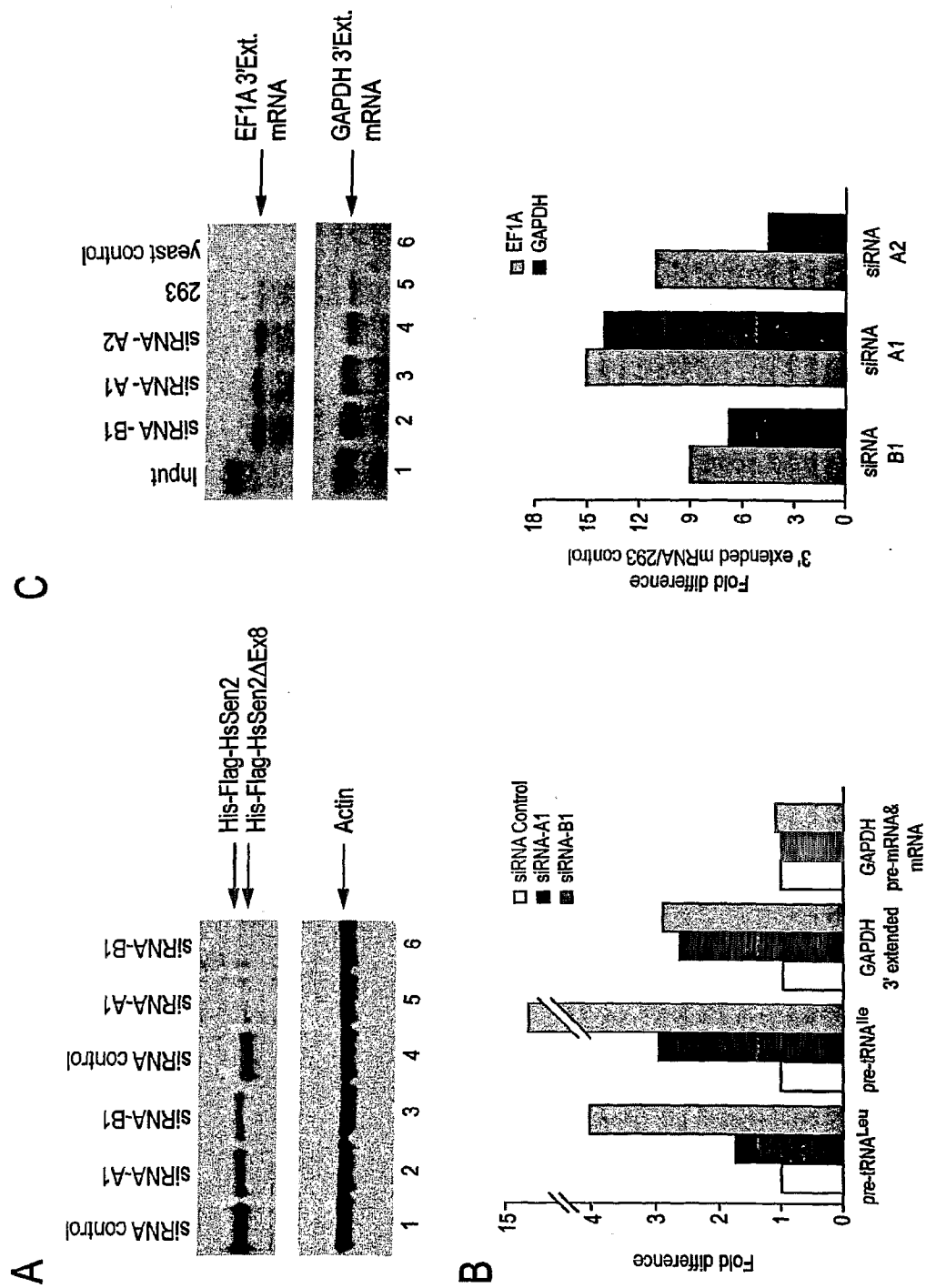


Fig. 30A-C



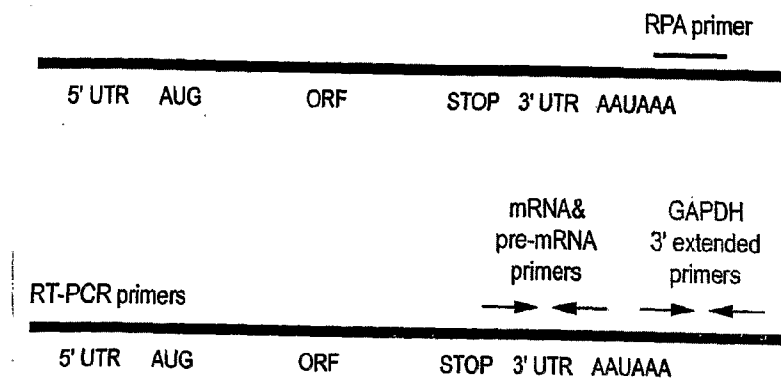


Fig. 30 D

## SEQUENCE LISTING

&lt;110&gt; PTC Therapeutics

&lt;120&gt; RNA Processing Protein Complexes and Uses Thereof

&lt;130&gt; 10589-041

&lt;150&gt; US 60/484,615

&lt;151&gt; 2003-07-02

&lt;160&gt; 37

&lt;170&gt; PatentIn version 3.2

&lt;210&gt; 1

&lt;211&gt; 2373

&lt;212&gt; DNA

&lt;213&gt; Homo sapeins

&lt;400&gt; 1

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agccggccga gacagtgccg ggacggggag ccaggcttcc gagtgcgccc ggtcactgac      180
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tcagggctgg tggggctggg gcgcaagggtg cagctgacaa tgcccgagag gagccgcagc      300
ctctggtgga gttcggtcgg gtgtgggggt agtcaaggaa agaagcaaag ggaataacctc      360
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acttacgagt ctccattgcc aatccctttt ggtcaggacc atggtcctct gaaagaattc      480
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caggggcagg atgagagtac agtgcgcaga atcctcaagg attacacgaa accgcttgag      780
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ggaaagtcag gtggtgtggg tgatccccgt gagccattag gctgcctgca ggagggtct      960
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cccatgtct gttgctgcaa acaagatgct ctcatctcc agcgtggcct tcatcatgaa      1080
gacggcagcc agcacatcgg cctcctgcat cctggggaca gagggcctga ccatgagtac      1140
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```

```

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acgttcagaa ccacctacat ggcttaccat tactttcgaa gcaagggctg ggtgccccaa 1440
gtgggactca agtacgggac agatttactg ctatatcgga aaggccctcc attttaccat 1500
gcaagttatt ctgtcattat cgagctagtt gatgaccatt ttgaaggctc tctccgcagg 1560
cctctcagtt ggaagtccct ggctgccttg agcagagttt ccgttaatgt ctctaaggaa 1620
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gaatgtatga aaaggattaa agttcaggag gtgattctga gtcgatgggt ttcttcacga 1740
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ctaactcccc catccagagc ctctgcctc tggcgtcagt tttttccctc atccactcac 2040
tggggagatt ggactagagg agtcttgaga ggacacttcc aacaagagac atttattctc 2100
tgattttacc tgaaaatggg agtagtttac atttatacag tacagtttat gaagcacttt 2160
catacgagg catctcttgt .tacctacatc taagctgttc ccgaaagagt gttacagaac 2220
acaacagtat tgtacaatat tcgataagca tatcttcaact gcacttgta taaaaatgag 2280
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gcctttttgt aattggtgaa aaaaaaaaaa aaa 2373

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&lt;210&gt; 2

&lt;211&gt; 465

&lt;212&gt; PRT

&lt;213&gt; Homo sapiens

&lt;400&gt; 2

```

Met Ala Glu Ala Val Phe His Ala Pro Lys Arg Lys Arg Arg Val Tyr
1           5           10           15

```

```

Glu Thr Tyr Glu Ser Pro Leu Pro Ile Pro Phe Gly Gln Asp His Gly
20           25           30

```

```

Pro Leu Lys Glu Phe Lys Ile Phe Arg Ala Glu Met Ile Asn Asn Asn
35           40           45

```

Val Ile Val Arg Asn Ala Glu Asp Ile Glu Gln Leu Tyr Gly Lys Gly  
 50 55 60

Tyr Phe Gly Lys Gly Ile Leu Ser Arg Ser Arg Pro Ser Phe Thr Ile  
 65 70 75 80

Ser Asp Pro Lys Leu Val Ala Lys Trp Lys Asp Met Lys Thr Asn Met  
 85 90 95

Pro Ile Ile Thr Ser Lys Arg Tyr Gln His Ser Val Glu Trp Ala Ala  
 100 105 110

Glu Leu Met Arg Arg Gln Gly Gln Asp Glu Ser Thr Val Arg Arg Ile  
 115 120 125

Leu Lys Asp Tyr Thr Lys Pro Leu Glu His Pro Pro Val Lys Arg Asn  
 130 135 140

Glu Glu Ala Gln Val His Asp Lys Leu Asn Ser Gly Met Val Ser Asn  
 145 150 155 160

Met Glu Gly Thr Ala Gly Gly Glu Arg Pro Ser Val Val Asn Gly Asp  
 165 170 175

Ser Gly Lys Ser Gly Gly Val Gly Asp Pro Arg Glu Pro Leu Gly Cys  
 180 185 190

Leu Gln Glu Gly Ser Gly Cys His Pro Thr Thr Glu Ser Phe Glu Lys  
 195 200 205

Ser Val Arg Glu Asp Ala Ser Pro Leu Pro His Val Cys Cys Cys Lys  
 210 215 220

Gln Asp Ala Leu Ile Leu Gln Arg Gly Leu His His Glu Asp Gly Ser  
 225 230 235 240

Gln His Ile Gly Leu Leu His Pro Gly Asp Arg Gly Pro Asp His Glu  
 245 250 255

Tyr Val Leu Val Glu Glu Ala Glu Cys Ala Met Ser Glu Arg Glu Ala  
 260 265 270

Ala Pro Asn Glu Glu Leu Val Gln Arg Asn Arg Leu Ile Cys Arg Arg  
 275 280 285

Asn Pro Tyr Arg Ile Phe Glu Tyr Leu Gln Leu Ser Leu Glu Glu Ala  
 290 295 300

Phe Phe Leu Val Tyr Ala Leu Gly Cys Leu Ser Ile Tyr Tyr Glu Lys  
 305 310 315 320

Glu Pro Leu Thr Ile Val Lys Leu Trp Lys Ala Phe Thr Val Val Gln  
 325 330 335

Pro Thr Phe Arg Thr Thr Tyr Met Ala Tyr His Tyr Phe Arg Ser Lys  
 340 345 350

Gly Trp Val Pro Lys Val Gly Leu Lys Tyr Gly Thr Asp Leu Leu Leu  
 355 360 365

Tyr Arg Lys Gly Pro Pro Phe Tyr His Ala Ser Tyr Ser Val Ile Ile  
 370 375 380

Glu Leu Val Asp Asp His Phe Glu Gly Ser Leu Arg Arg Pro Leu Ser  
 385 390 395 400

Trp Lys Ser Leu Ala Ala Leu Ser Arg Val Ser Val Asn Val Ser Lys  
 405 410 415

Glu Leu Met Leu Cys Tyr Leu Ile Lys Pro Ser Thr Met Thr Asp Lys  
 420 425 430

Glu Met Glu Ser Pro Glu Cys Met Lys Arg Ile Lys Val Gln Glu Val  
 435 440 445

Ile Leu Ser Arg Trp Val Ser Ser Arg Glu Arg Ser Asp Gln Asp Asp  
 450 455 460

Leu  
 465

<210> 3  
 <211> 1943  
 <212> DNA  
 <213> Homo sapiens

<400> 3  
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taaaattaaa aaaaaaaaaa aaa	1943

<210> 4  
 <211> 171  
 <212> PRT  
 <213> Homo sapiens

<400> 4

Met Glu Glu Arg Gly Asp Ser Glu Pro Thr Pro Gly Cys Ser Gly Leu  
 1 5 10 15

Gly Pro Gly Gly Val Arg Gly Phe Gly Asp Gly Gly Gly Ala Pro Ser  
 20 25 30

Trp Ala Pro Glu Asp Ala Trp Met Gly Thr His Pro Lys Tyr Leu Glu  
 35 40 45

Met Met Glu Leu Asp Ile Gly Asp Ala Thr Gln Val Tyr Val Ala Phe  
 50 55 60

Leu Val Tyr Leu Asp Leu Met Glu Ser Lys Ser Trp His Glu Val Asn  
 65 70 75 80

Cys Val Gly Leu Pro Glu Leu Gln Leu Ile Cys Leu Val Gly Thr Glu  
 85 90 95

Ile Glu Gly Glu Gly Leu Gln Thr Val Val Pro Thr Pro Ile Thr Ala  
 100 105 110

Ser Leu Ser His Asn Arg Ile Arg Glu Ile Leu Lys Ala Ser Arg Lys  
 115 120 125

Leu Gln Gly Asp Pro Asp Leu Pro Met Ser Phe Thr Leu Ala Ile Val  
 130 135 140

Glu Ser Asp Ser Thr Ile Val Tyr Tyr Lys Leu Thr Asp Gly Phe Met  
 145 150 155 160

Leu Pro Asp Pro Gln Asn Ile Ser Leu Arg Arg  
 165 170

<210> 5  
 <211> 1364  
 <212> DNA

<213> Homo sapiens

<400> 5

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ctcgcgcttg ggccctccgc tgctgctgat gccgaagag gcgcggctct tggccgagat      300
cggcgccgtg actctggtca gcgccccgcg tccagactct cggcaccaca gcctggccct      360
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cccctcgtct tccaagcag gacctcaaa tggggtagcc cccttgccca gatctgctct      660
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tgtccagtct aaagactggc ccacgcgcg ccgccctgcc cagcagctgc gctacagtat      780
ctacagagac ctgtgggagc gaggcttctt cctcagtgcg gctggcaagt tcggagggtga      840
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ggccctgag gacacctccc actccaagac ctggttgctg ctgggcgcct tggaaccagc      960
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&lt;210&gt; 6

&lt;211&gt; 390

&lt;212&gt; PRT

&lt;213&gt; Homo sapiens

&lt;400&gt; 6

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Met Leu Val Val Glu Val Ala Asn Gly Arg Ser Leu Val Trp Gly Ala
1           5           10          15

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Glu Ala Val Gln Ala Leu Arg Glu Arg Leu Gly Val Gly Gly Arg Thr
20          25          30

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Val Gly Ala Leu Pro Arg Gly Pro Arg Gln Asn Ser Arg Leu Gly Leu
35          40          45

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Pro Leu Leu Leu Met Pro Glu Glu Ala Arg Leu Leu Ala Glu Ile Gly  
 50 55 60

Ala Val Thr Leu Val Ser Ala Pro Arg Pro Asp Ser Arg His His Ser  
 65 70 75 80

Leu Ala Leu Thr Ser Phe Lys Arg Gln Gln Glu Glu Ser Phe Gln Glu  
 85 90 95

Gln Ser Ala Leu Ala Ala Glu Ala Arg Glu Thr Arg Arg Gln Glu Val  
 100 105 110

Leu Glu Lys Ile Thr Glu Gly Gln Ala Ala Lys Lys Gln Lys Leu Glu  
 115 120 125

Gln Ala Ser Gly Ala Ser Ser Ser Gln Glu Ala Gly Ser Ser Gln Ala  
 130 135 140

Ala Lys Glu Asp Glu Thr Ser Asp Gly Gln Ala Ser Gly Glu Gln Glu  
 145 150 155 160

Glu Ala Gly Pro Ser Ser Ser Gln Ala Gly Pro Ser Asn Gly Val Ala  
 165 170 175

Pro Leu Pro Arg Ser Ala Leu Leu Val Gln Leu Ala Thr Ala Arg Pro  
 180 185 190

Arg Pro Val Lys Ala Arg Pro Leu Asp Trp Arg Val Gln Ser Lys Asp  
 195 200 205

Trp Pro His Ala Gly Arg Pro Ala His Glu Leu Arg Tyr Ser Ile Tyr  
 210 215 220

Arg Asp Leu Trp Glu Arg Gly Phe Phe Leu Ser Ala Ala Gly Lys Phe  
 225 230 235 240

Gly Gly Asp Phe Leu Val Tyr Pro Gly Asp Pro Leu Arg Phe His Ala  
 245 250 255

His Tyr Ile Ala Gln Cys Trp Ala Pro Glu Asp Thr Ser His Ser Lys  
 260 265 270

Thr Trp Leu Leu Leu Gly Ala Leu Glu Pro Ala Ser Glu Arg Pro Cys  
 275 280 285

Ser Ser Val Leu Arg Ser Leu Met Val Arg Trp Ser Thr Pro Pro Cys  
 290 295 300

Asn Gly Pro Ala Cys Ser Glu Leu Gln Arg Pro Arg Gly Cys Gly Cys  
 305 310 315 320

Val Gly Ser Lys Ser Leu Ser Gly Cys Ser Pro Ala Leu Leu Trp Glu  
 325 330 335

Ser Arg Thr Ser Ser Tyr Leu Ser Pro Arg Leu Val Phe Asp Ser Arg  
 340 345 350

Phe Ser Asn Thr Thr Ser Phe Leu Cys Ser Ser Leu Phe Gln Ser Thr  
 355 360 365

Tyr Trp Leu Cys Phe Cys Ser Tyr Leu Phe Ser His Cys Glu Leu Pro  
 370 375 380

Glu Asn Gly Ala Trp Val  
 385 390

<210> 7  
 <211> 1932  
 <212> DNA  
 <213> Homo sapiens

<400> 7  
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 cttaccagct gctgctgacc gaccacactg tgaccttcc gcagtaccag gtcttcagcc 480  
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 gccagagga gaaacccag gagtcaagcc ccatgaaggg cccagggggc ccctttcagc 780

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agatctcctt ccccaacatg gcttcagaca gccgccacac ctttctgcgc gcccagccc      960
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agtacaagga gctgctgcag cggcggcagg tgcagaggag ccagcgccgg gccctcacc    1200
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tttaaggacc caggaggtgg ggcagaagag aggactgtgt gcctttaacg agagggtgcc    1860
tgcttcgtgc tataaagcca aagccattaa aaatagattt cttttaaaaa aaaaaaaaaa    1920
aaaaaaaaaa aa                                                              1932

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<210> 8  
 <211> 526  
 <212> PRT  
 <213> Homo sapiens

<400> 8

Met Glu Pro Asp Pro Glu Pro Ala Ala Val Glu Val Pro Ala Gly Arg  
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Val Leu Ser Ala Arg Glu Leu Phe Ala Ala Arg Ser Arg Ser Gln Lys  
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Leu Pro Gln Arg Ser His Gly Pro Lys Asp Phe Leu Pro Asp Gly Ser  
 35 40 45

Ala Ala Gln Ala Glu Arg Leu Arg Arg Cys Arg Glu Glu Leu Trp Gln  
 50 55 60

Leu Leu Ala Glu Gln Arg Val Glu Arg Leu Gly Ser Leu Val Ala Ala  
 65 70 75 80

Glu Trp Arg Pro Glu Glu Gly Phe Val Glu Leu Lys Ser Pro Ala Gly  
 85 90 95

Lys Phe Trp Gln Thr Met Gly Phe Ser Glu Gln Gly Arg Gln Arg Leu  
 100 105 110

His Pro Glu Glu Ala Leu Tyr Leu Leu Glu Cys Gly Ser Ile His Leu  
 115 120 125

Phe His Gln Asp Leu Pro Leu Ser Ile Gln Glu Ala Tyr Gln Leu Leu  
 130 135 140

Leu Thr Asp His Thr Val Thr Phe Leu Gln Tyr Gln Val Phe Ser His  
 145 150 155 160

Leu Lys Arg Leu Gly Tyr Val Val Arg Arg Phe Gln Pro Ser Ser Val  
 165 170 175

Leu Ser Pro Tyr Glu Arg Gln Leu Asn Leu Asp Ala Ser Val Gln His  
 180 185 190

Leu Glu Asp Gly Asp Gly Lys Arg Lys Arg Ser Ser Ser Ser Pro Arg  
 195 200 205

Ser Ile Asn Lys Lys Ala Lys Ala Leu Asp Asn Ser Leu Gln Pro Lys  
 210 215 220

Ser Leu Ala Ala Ser Ser Pro Pro Pro Cys Ser Gln Pro Ser Gln Cys  
 225 230 235 240

Pro Glu Glu Lys Pro Gln Glu Ser Ser Pro Met Lys Gly Pro Gly Gly  
 245 250 255

Pro Phe Gln Leu Leu Gly Ser Leu Gly Pro Ser Pro Gly Pro Ala Arg  
 260 265 270

Glu Gly Val Gly Cys Ser Trp Glu Ser Gly Arg Ala Glu Asn Gly Val  
 275 280 285

12/23

Thr Gly Ala Gly Lys Arg Arg Trp Asn Phe Glu Gln Ile Ser Phe Pro  
 290 295 300

Asn Met Ala Ser Asp Ser Arg His Thr Leu Leu Arg Ala Pro Ala Pro  
 305 310 315 320

Glu Leu Leu Pro Ala Asn Val Ala Gly Arg Glu Thr Asp Ala Glu Ser  
 325 330 335

Trp Cys Gln Lys Leu Asn Gln Arg Lys Glu Asn Leu Ser Arg Arg Glu  
 340 345 350

Arg Glu His His Ala Glu Ala Ala Gln Phe Gln Glu Asp Val Asn Ala  
 355 360 365

Asp Pro Glu Val Gln Arg Cys Ser Ser Trp Arg Glu Tyr Lys Glu Leu  
 370 375 380

Leu Gln Arg Arg Gln Val Gln Arg Ser Gln Arg Arg Ala Pro His Leu  
 385 390 395 400

Trp Gly Gln Pro Val Thr Pro Leu Leu Ser Pro Gly Gln Ala Ser Ser  
 405 410 415

Pro Ala Val Val Leu Gln His Ile Ser Val Leu Gln Thr Thr His Leu  
 420 425 430

Pro Asp Gly Gly Val Arg Leu Leu Glu Lys Ser Gly Gly Leu Glu Ile  
 435 440 445

Ile Phe Asp Val Tyr Gln Ala Asp Ala Val Ala Thr Phe Arg Lys Asn  
 450 455 460

Asn Pro Gly Lys Pro Tyr Ala Arg Met Cys Ile Ser Gly Phe Asp Glu  
 465 470 475 480

Pro Val Pro Asp Leu Cys Ser Leu Lys Arg Leu Ser Tyr Gln Ser Gly  
 485 490 495

Asp Val Pro Leu Ile Phe Ala Leu Val Asp His Gly Asp Ile Ser Phe  
 500 505 510

Tyr Ser Phe Arg Asp Phe Thr Leu Pro Gln Asp Val Gly His  
 515 520 525

&lt;211&gt; 1852

&lt;212&gt; DNA

&lt;213&gt; Homo sapiens

&lt;400&gt; 9

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 aaatcatttt aataaatatt tttgccatat cataaaaaaa aaaaaaaaaa aa 1852

<210> 10  
 <211> 425  
 <212> PRT  
 <213> Homo sapiens

<400> 10

Met Gly Glu Glu Ala Asn Asp Asp Lys Lys Pro Thr Thr Lys Phe Glu  
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 20 25 30

Val Gln Leu Glu Leu Leu Thr Gly Met Ala Glu Ile Phe Gly Thr Glu  
 35 40 45

Leu Thr Arg Asn Lys Lys Phe Thr Phe Asp Ala Gly Ala Lys Val Ala  
 50 55 60

Val Phe Thr Trp His Gly Cys Ser Val Gln Leu Ser Gly Arg Thr Glu  
 65 70 75 80

Val Ala Tyr Val Ser Lys Asp Thr Pro Met Leu Leu Tyr Leu Asn Thr  
 85 90 95

His Thr Ala Leu Glu Gln Met Arg Arg Gln Ala Glu Lys Glu Glu Glu  
 100 105 110

Arg Gly Pro Arg Val Met Val Val Gly Pro Thr Asp Val Gly Lys Ser  
 115 120 125

Thr Val Cys Arg Leu Leu Leu Asn Tyr Ala Val Arg Leu Gly Arg Arg  
 130 135 140

Pro Thr Tyr Val Glu Leu Asp Val Gly Gln Gly Ser Val Ser Ile Pro  
 145 150 155 160

Gly Thr Met Gly Ala Leu Tyr Ile Glu Arg Pro Ala Asp Val Glu Glu  
 165 170 175

Gly Phe Ser Ile Gln Ala Pro Leu Val Tyr His Phe Gly Ser Thr Thr  
 180 185 190

Pro Gly Thr Asn Ile Lys Leu Tyr Asn Lys Ile Thr Ser Arg Leu Ala  
 195 200 205

Asp Val Phe Asn Gln Arg Cys Glu Val Asn Arg Arg Ala Ser Val Ser  
 210 215 220

Gly Cys Val Ile Asn Thr Cys Gly Trp Val Lys Gly Ser Gly Tyr Gln  
 225 230 235 240

Ala Leu Val His Ala Ala Ser Ala Phe Glu Val Asp Val Val Val Val  
 245 250 255

Leu Asp Gln Glu Arg Leu Tyr Asn Glu Leu Lys Arg Asp Leu Pro His  
 260 265 270

Phe Val Arg Thr Val Leu Leu Pro Lys Ser Gly Gly Val Val Glu Arg  
 275 280 285

Ser Lys Asp Phe Arg Arg Glu Cys Arg Asp Glu Arg Ile Arg Glu Tyr  
 290 295 300

Phe Tyr Gly Phe Arg Gly Cys Phe Tyr Pro His Ala Phe Asn Val Lys  
 305 310 315 320

Phe Ser Asp Val Lys Ile Tyr Lys Val Gly Ala Pro Thr Ile Pro Asp  
 325 330 335

Ser Cys Leu Pro Leu Gly Met Ser Gln Glu Asp Asn Gln Leu Lys Leu  
 340 345 350

Val Pro Val Thr Pro Gly Arg Asp Met Val His His Leu Leu Ser Val  
 355 360 365

Ser Thr Ala Glu Gly Thr Glu Glu Asn Leu Ser Glu Thr Ser Val Ala  
 370 375 380

Gly Phe Ile Val Val Thr Ser Val Asp Leu Glu His Gln Val Phe Thr  
 385 390 395 400

Val Leu Ser Pro Ala Pro Arg Pro Leu Pro Lys Asn Phe Leu Leu Ile  
 405 410 415

Met Asp Ile Arg Phe Met Asp Leu Lys  
 420 425



<210> 11  
 <211> 1347  
 <212> DNA  
 <213> Homo sapiens

<400> 11  
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Glu Thr Tyr Glu Ser Pro Leu Pro Ile Pro Phe Gly Gln Asp His Gly  
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Pro Leu Lys Glu Phe Lys Ile Phe Arg Ala Glu Met Ile Asn Asn Asn  
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Val Ile Val Arg Asn Ala Glu Asp Ile Glu Gln Leu Tyr Gly Lys Gly  
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Tyr Phe Gly Lys Gly Ile Leu Ser Arg Ser Arg Pro Ser Phe Thr Ile  
 65 70 75 80

Ser Asp Pro Lys Leu Val Ala Lys Trp Lys Asp Met Lys Thr Asn Met  
 85 90 95

Pro Ile Ile Thr Ser Lys Arg Tyr Gln His Ser Val Glu Trp Ala Ala  
 100 105 110

Glu Leu Met Arg Arg Gln Gly Gln Asp Glu Ser Thr Val Arg Arg Ile  
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Leu Lys Asp Tyr Thr Lys Pro Leu Glu His Pro Pro Val Lys Arg Asn  
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Glu Glu Ala Gln Val His Asp Lys Leu Asn Ser Gly Met Val Ser Asn  
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Met Glu Gly Thr Ala Gly Gly Glu Arg Pro Ser Val Val Asn Gly Asp  
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Ser Gly Lys Ser Gly Gly Val Gly Asp Pro Arg Glu Pro Leu Gly Cys  
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Leu Gln Glu Gly Ser Gly Cys His Pro Thr Thr Glu Ser Phe Glu Lys  
 195 200 205

Ser Val Arg Glu Asp Ala Ser Pro Leu Pro His Val Cys Cys Cys Lys  
 210 215 220

Gln Asp Ala Leu Ile Leu Gln Arg Gly Leu His His Glu Asp Gly Ser  
 225 230 235 240

Gln His Ile Gly Leu Leu His Pro Gly Asp Arg Gly Pro Asp His Glu  
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Tyr Val Leu Val Glu Glu Ala Glu Cys Ala Met Ser Glu Arg Glu Ala  
260 265 270

Ala Pro Asn Glu Glu Leu Val Gln Arg Asn Arg Leu Ile Cys Arg Arg  
275 280 285

Asn Pro Tyr Arg Ile Phe Glu Tyr Leu Gln Leu Ser Leu Glu Glu Glu  
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Pro Leu Thr Ile Val Lys Leu Trp Lys Ala Phe Thr Val Val Gln Pro  
305 310 315 320

Thr Phe Arg Thr Thr Tyr Met Ala Tyr His Tyr Phe Arg Ser Lys Gly  
325 330 335

Trp Val Pro Lys Val Gly Leu Lys Tyr Gly Thr Asp Leu Leu Leu Tyr  
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Arg Lys Gly Pro Pro Phe Tyr His Ala Ser Tyr Ser Val Ile Ile Glu  
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Leu Val Asp Asp His Phe Glu Gly Ser Leu Arg Arg Pro Leu Ser Trp  
370 375 380

Lys Ser Leu Ala Ala Leu Ser Arg Val Ser Val Asn Val Ser Lys Glu  
385 390 395 400

Leu Met Leu Cys Tyr Leu Ile Lys Pro Ser Thr Met Thr Asp Lys Glu  
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